Coarse mode aerosol measurements during ACCLIP and SABRE

Photograph: Bernadett Weinzierl

Bernadett Weinzierl, Florian Kuderna, Maximilian Dollner, Nicholas Beres, Mirjam Rieser

With data from: CAPS, MMS (Bui et al.), DLH (Diskin et al.), UCATS (Hintsa, Moore et al.), PALMS (Murphy, Schill et al.), and Eric Ray

University of Vienna
Faculty of Physics
Aerosol Physics and Environmental Physics
1090 Vienna, Austria

ACCLIP & SABRE Science Team Meeting
1 May 2024, Boulder

Overview

Photos: Bernadett Weinzierl

- **Cold-SABRE 2023:**

  Hypothesis: Corse mode particle abundance is different inside and outside the polar vortex

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  Hypothesis: Corse mode particle abundance is different inside and outside the polar vortex

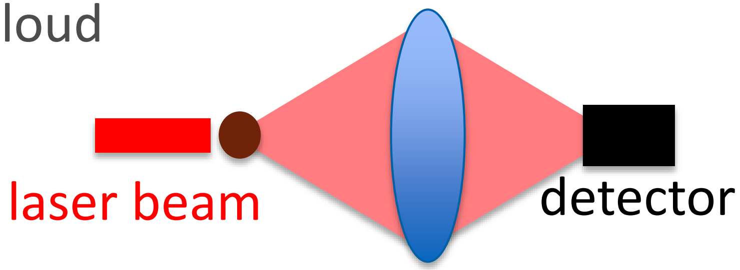
- **ACCLIP 2022:**

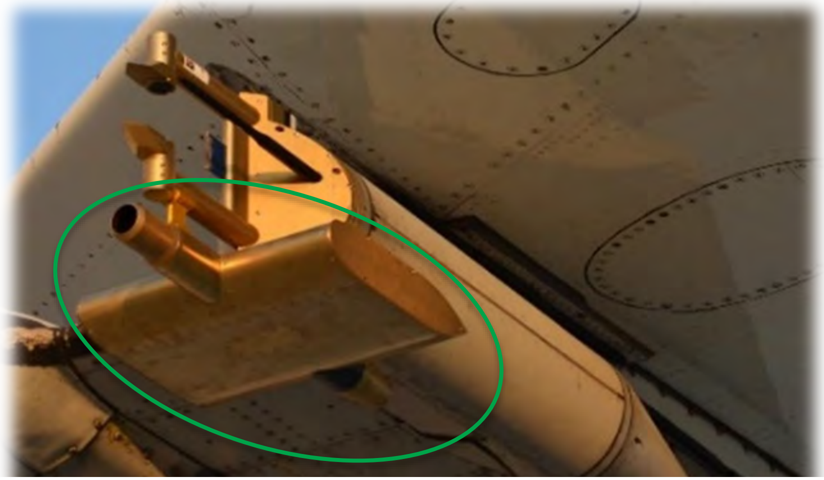
  An outlook to our planned analysis of mineral dust encounters at high altitude during ACCLIP

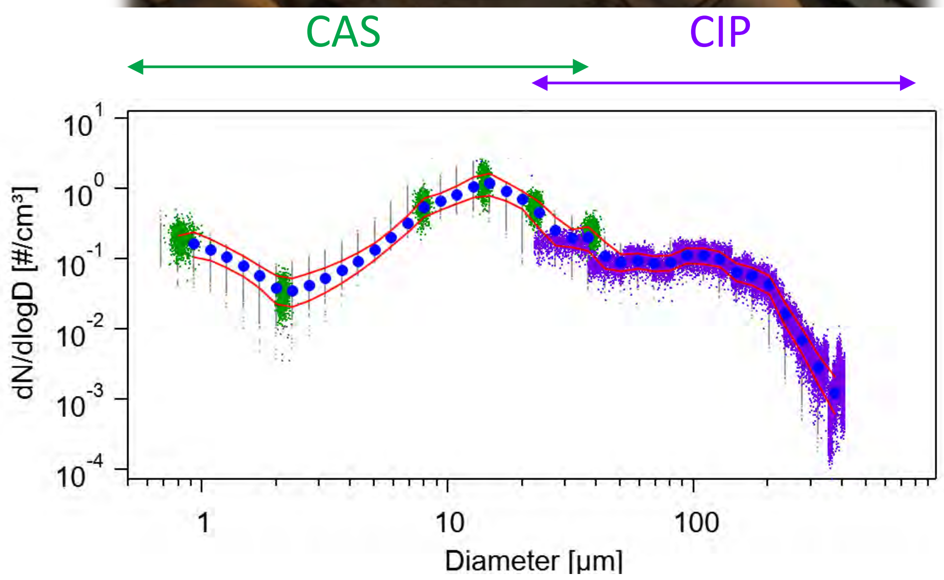
Second generation Cloud, Aerosol, and Precipitation Spectrometer (CAPS)

Component 1: Cloud and Aerosol Spectrometer (CAS):

- Optical particle counter (OPC)
- Size of aerosol and cloud particles between ~**0.5 and 50 µm**.







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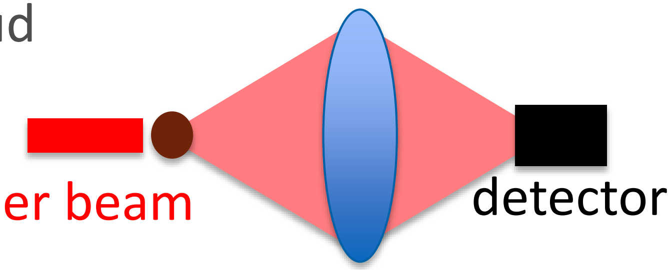
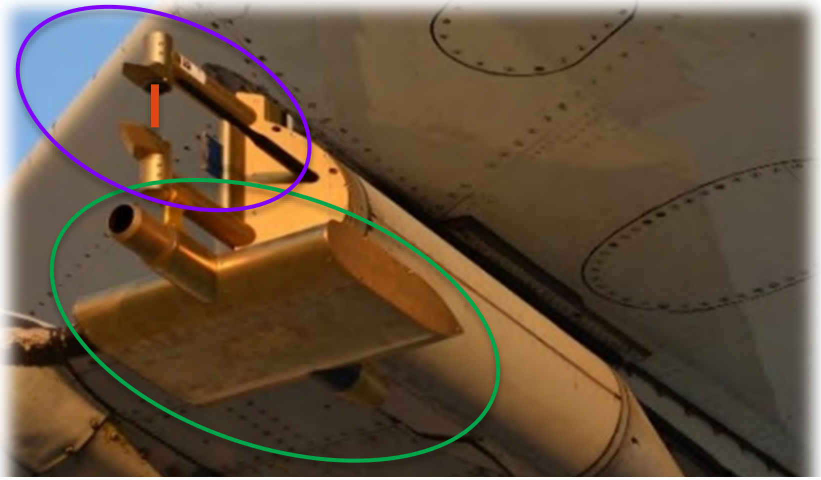
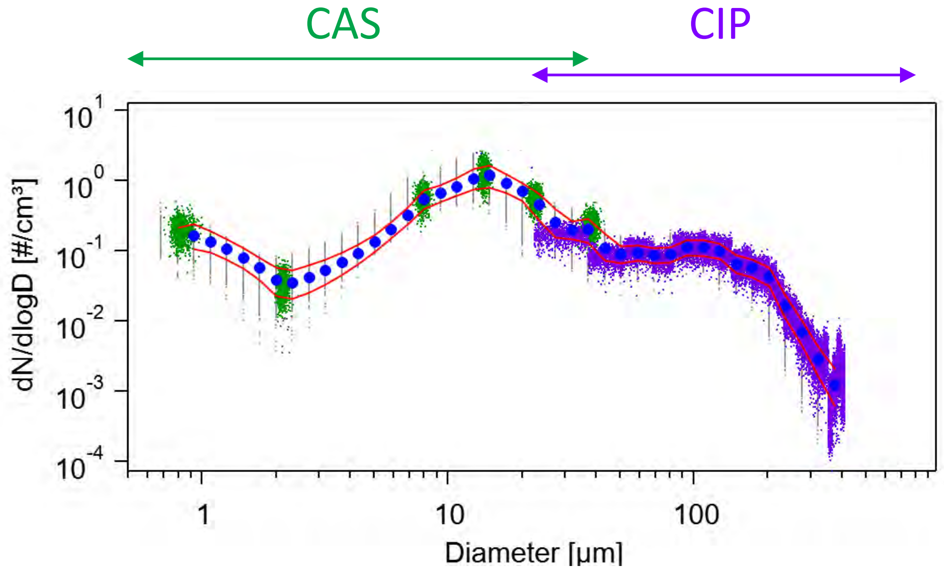
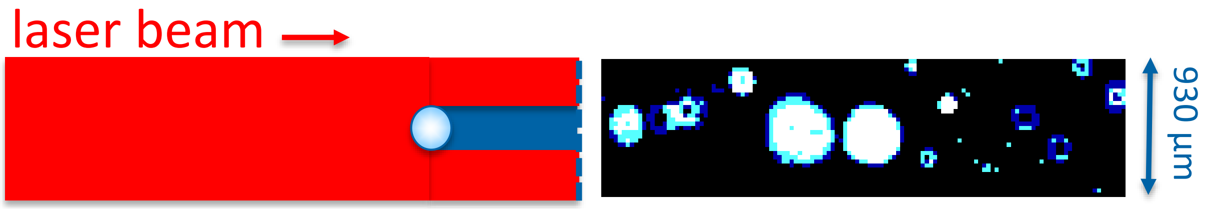






Component 2: Cloud Image Probe (CIP):

- Shadow Imager
- Images of aerosol and cloud particles from **15 to 930 µm**.



CAPS *Cloud Indicator* product

…based on CAPS data, RH (DLH), and T (MMS) data: Time_Start, Cloudindicator_CAPS, Cloudflag_CAPS

☐ WEINZIERL.BERNADETT/

Download	Filename	Recv'd/Updated	Size (KB)
☐	ACCLIP-CAPS-cloudindicator_WB57_20220714_R0.ict	20231003	154.5
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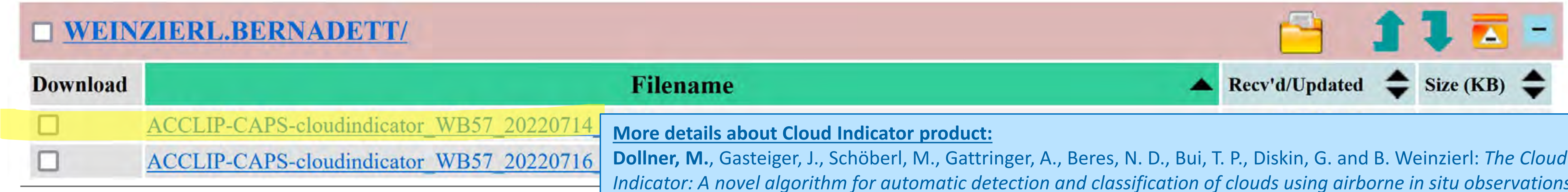
Note: in „Cloudflag_CAPS“, gaps of up to 10s between consecutive clouds are flagged as clouds to ensure a cloud-free data set.

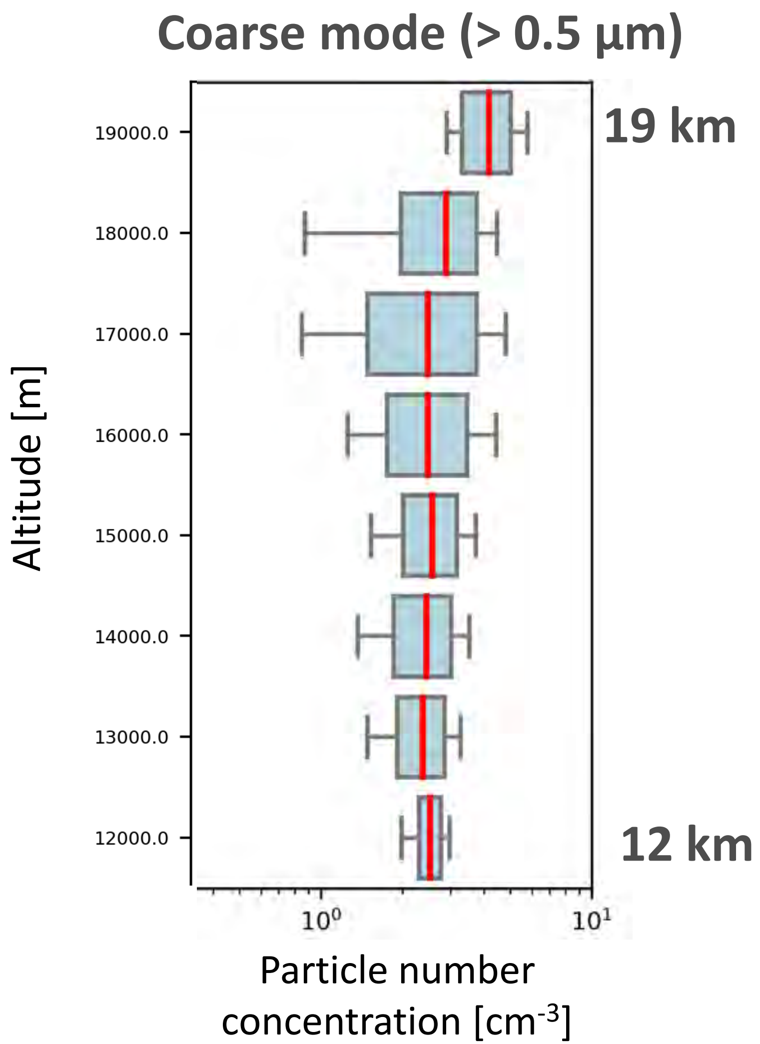


More details about Cloud Indicator product:

Dollner, M., Gasteiger, J., Schöberl, M., Gattringer, A., Beres, N. D., Bui, T. P., Diskin, G. and B. Weinzierl: *The Cloud Indicator: A novel algorithm for automatic detection and classification of clouds using airborne in situ observations*, Atmospheric Research [prePrint], http://dx.doi.org/10.2139/ssrn.4654136 , revised version submitted (2024)

bernadett.weinzierl@univie.ac.at

Average vertical profile of coarse mode number concentration during Cold-SABRE 2023



F. Kuderna (Master thesis Uni Vienna, 2024)

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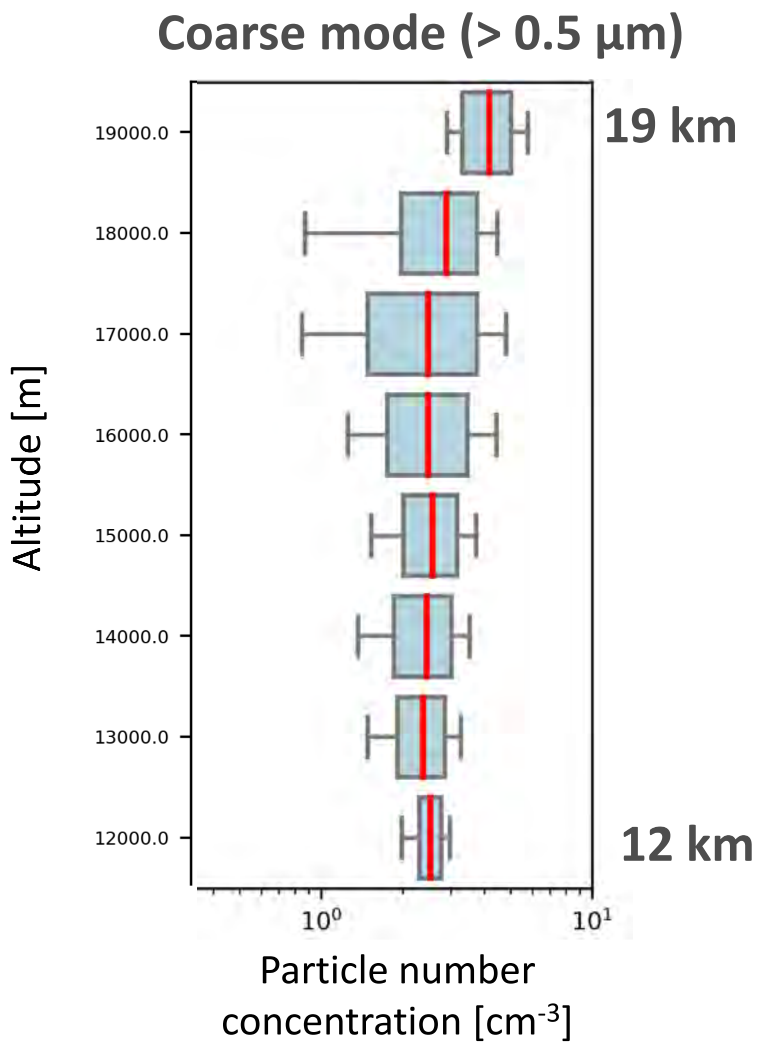

How can we separate measurements inside and outside the dynamical barrier of the polar vortex edge?

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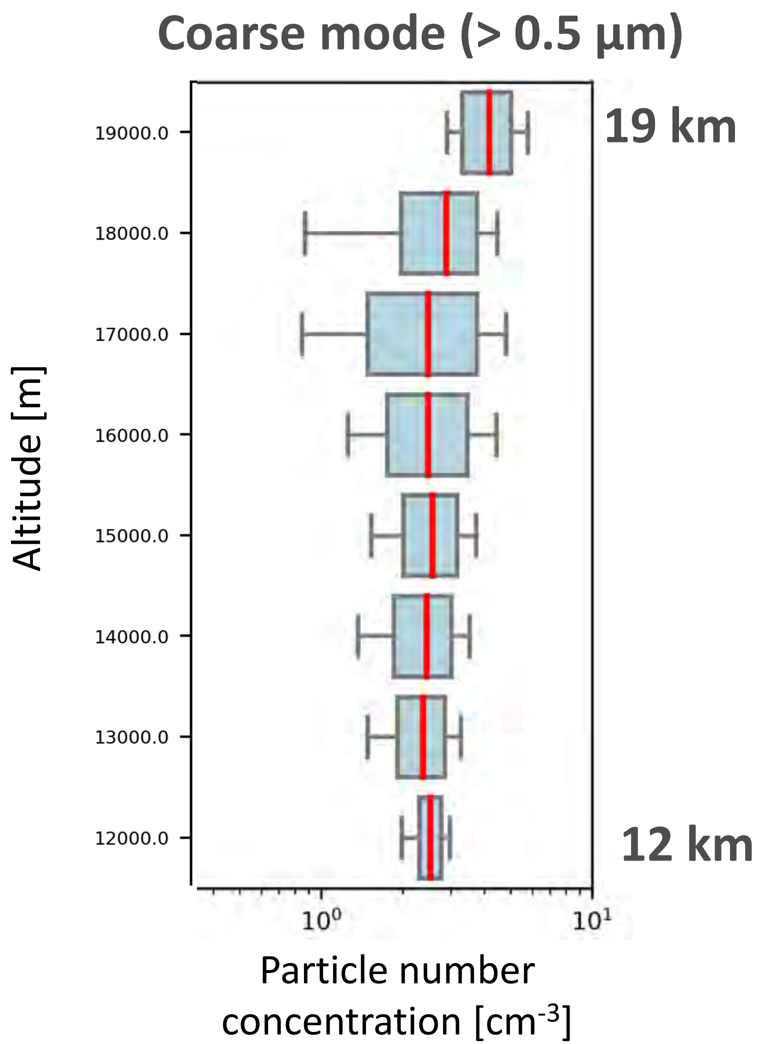

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- Vortex air is aged air that has reached high altitudes
- N_2O quasi constant (~340 ppb in 2023) in the well-mixed troposphere, gets injected into stratosphere in tropics
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$$N_2O + h\nu \rightarrow N_2 + O$$

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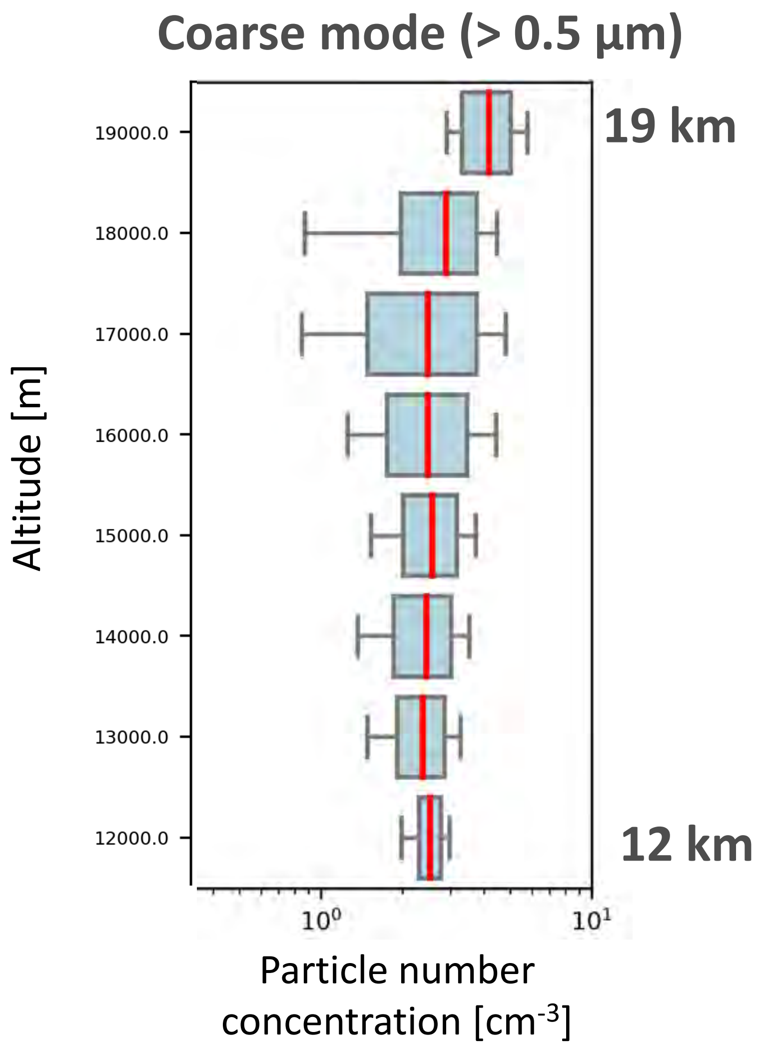

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- Longer & higher exposure to UV —> smaller N_2O concentrations
- **Easiest Solution**: Define a **N_2O cutoff value** (e.g. Dye et al., 1992)
- **BUT: there is a also vertical gradient in N_2O!**

F. Kuderna (Master thesis Uni Vienna, 2024)

Identify measurements inside the polar vortex: The „**Greenblatt algorithm**“

(Greenblatt et al., 2002a)

Identify measurements inside the polar vortex: The „**Greenblatt algorithm**“

1. **Find a reference flight that fulfills the “Nash criterion” (1996; potential vorticity value)**
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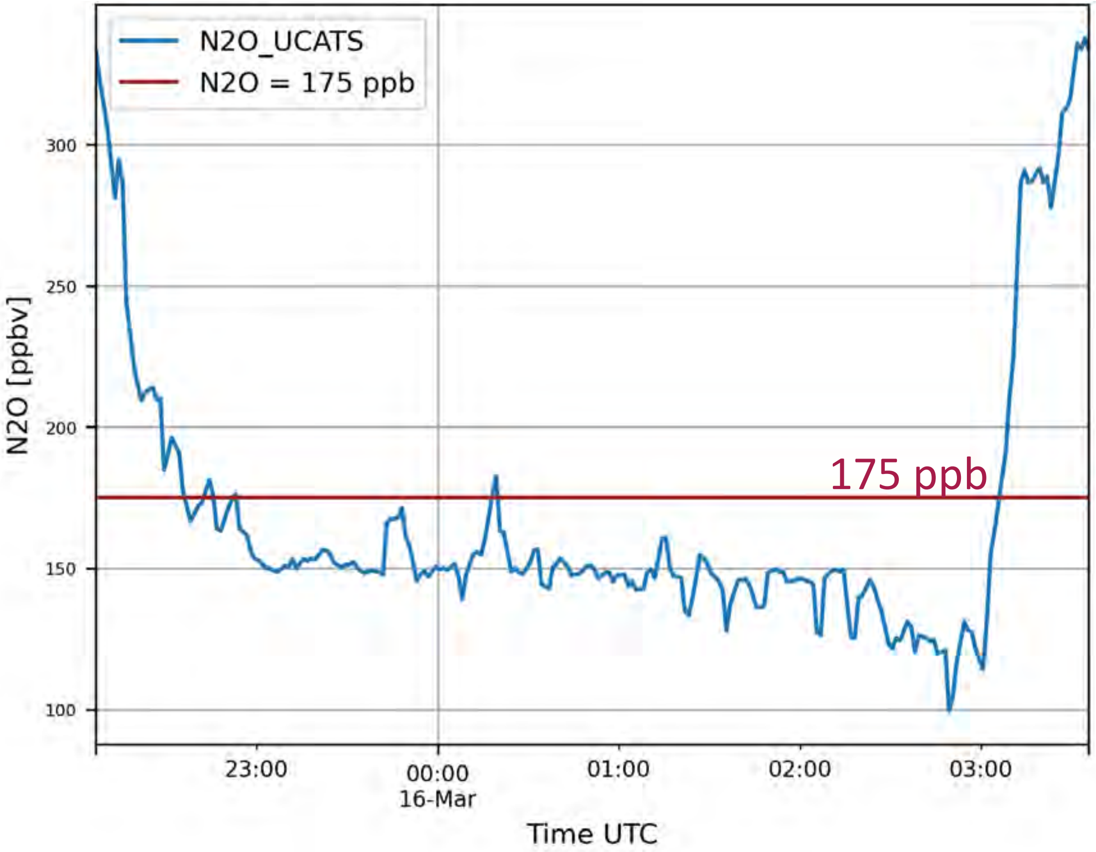
5. **Check whether a datapoint from other flights is inside of the inner edge of the vortex by calculating:**

$$\Delta N_2O = |N_2O - N_2O_{VOR}| < \text{cutoff}$$

(Greenblatt et al., 2002a)

Finding a reference flight: N_2O time series

15 March 2023



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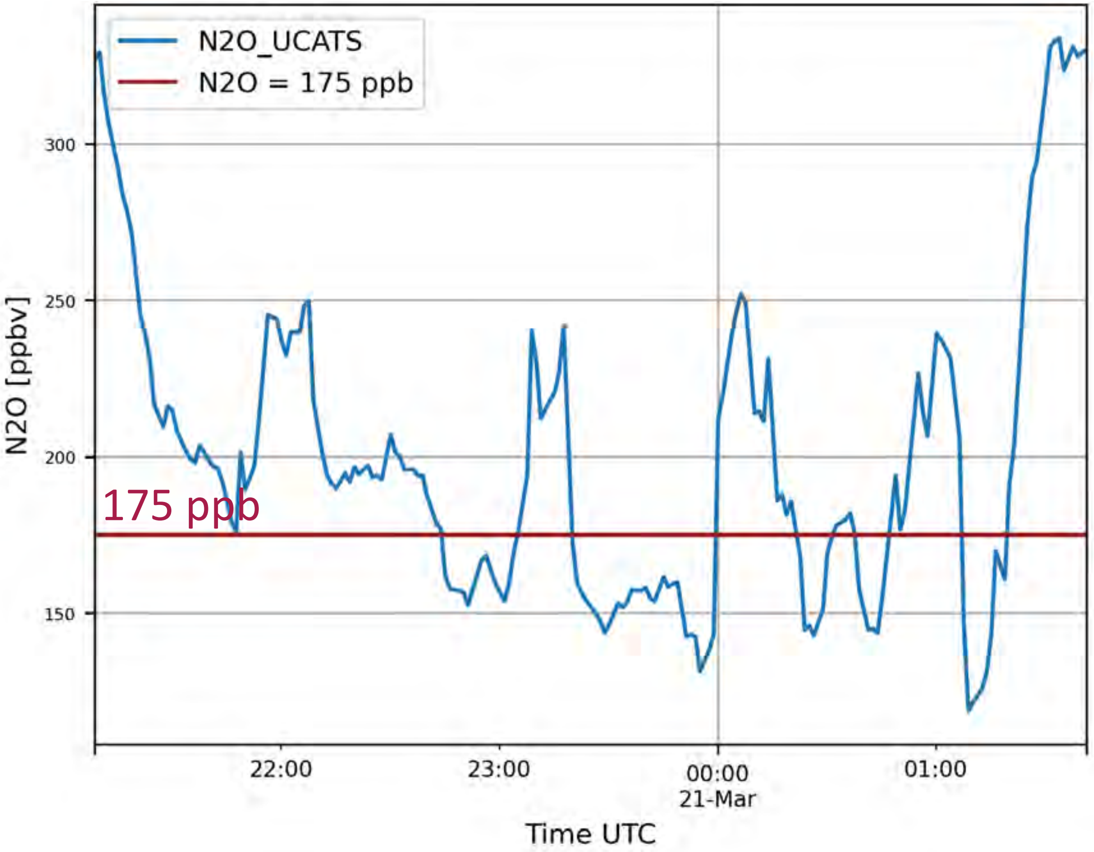

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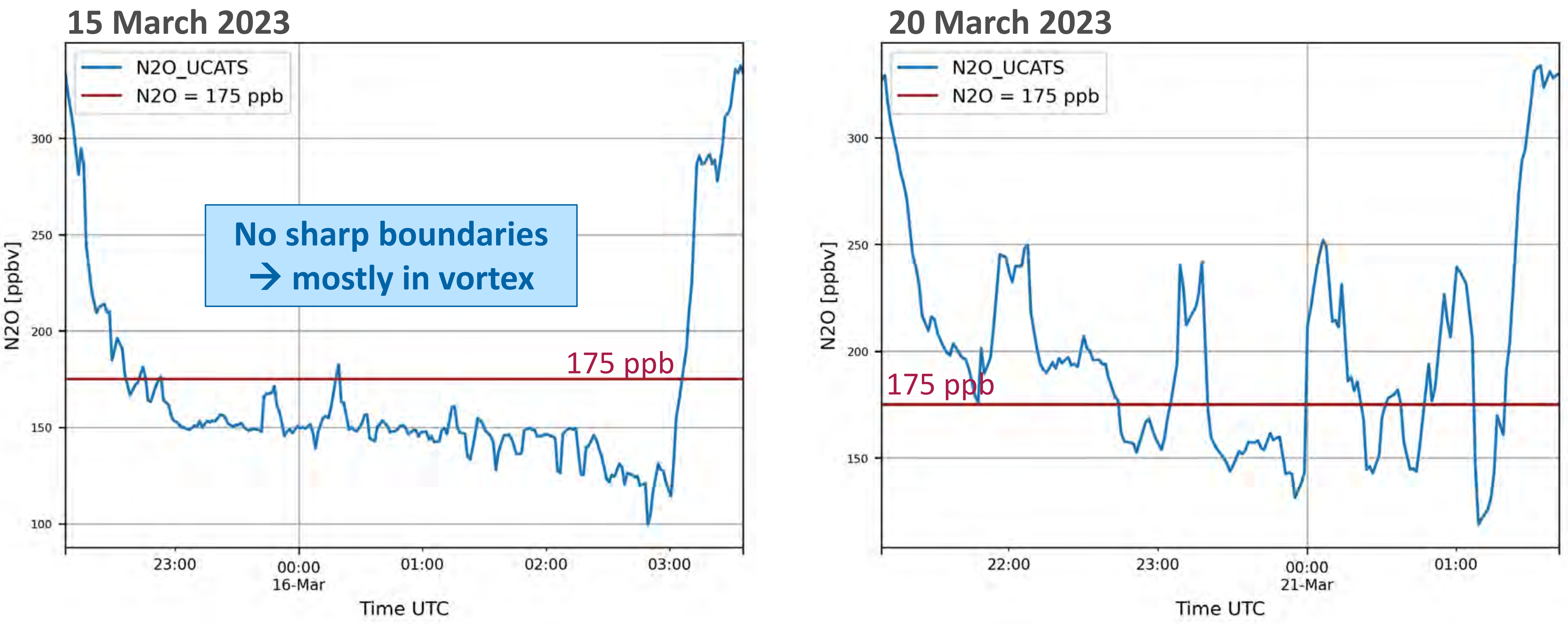

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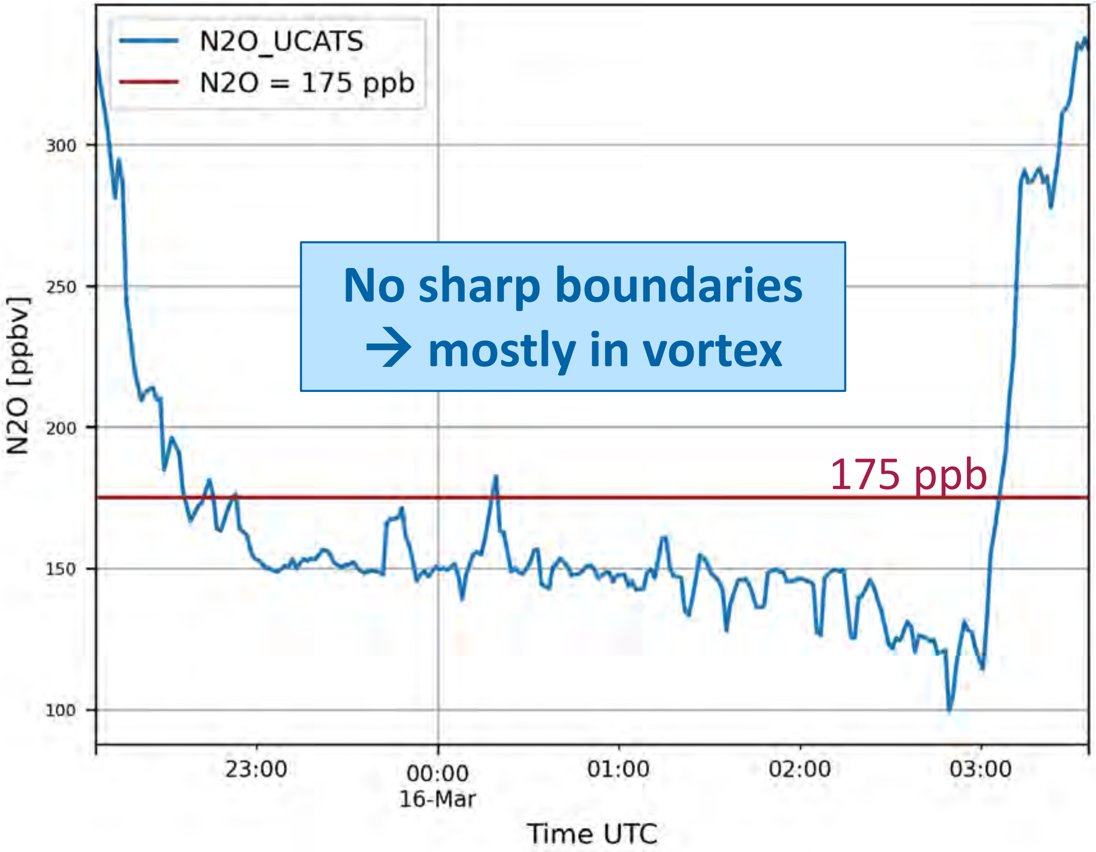

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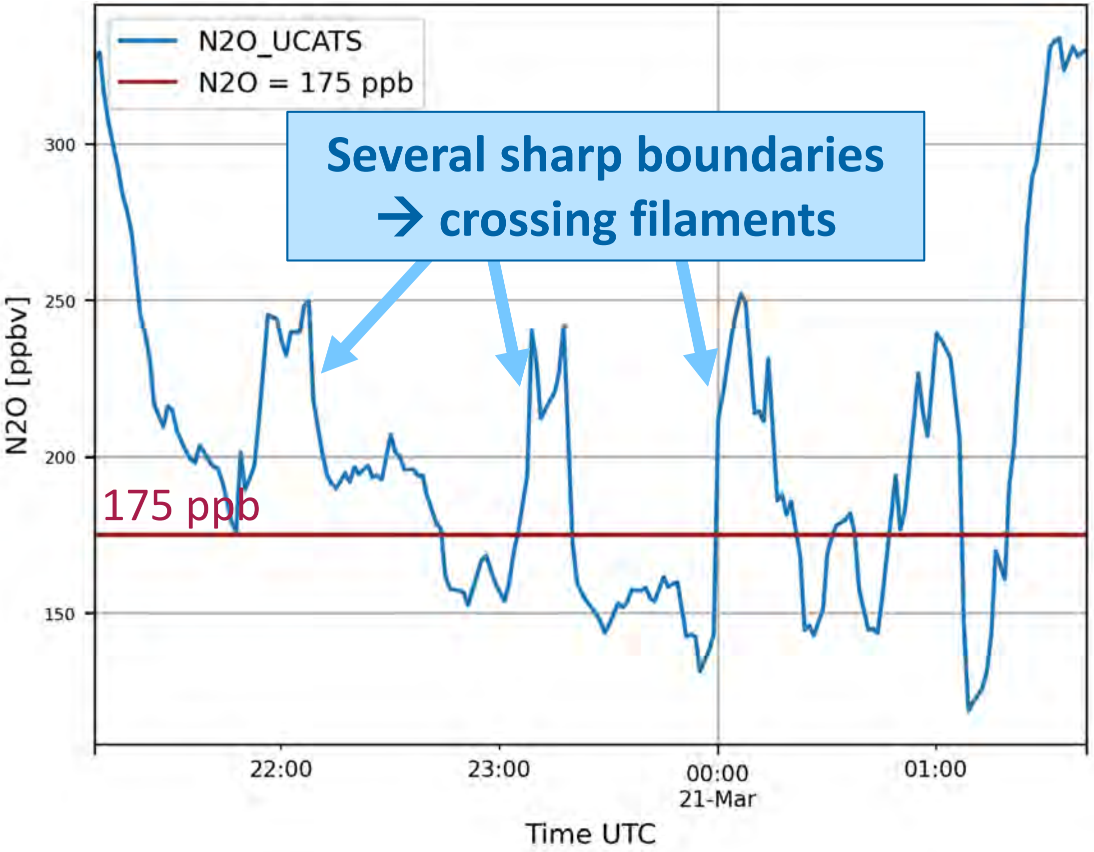

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Finding a reference flight: Θ vs. N_2O

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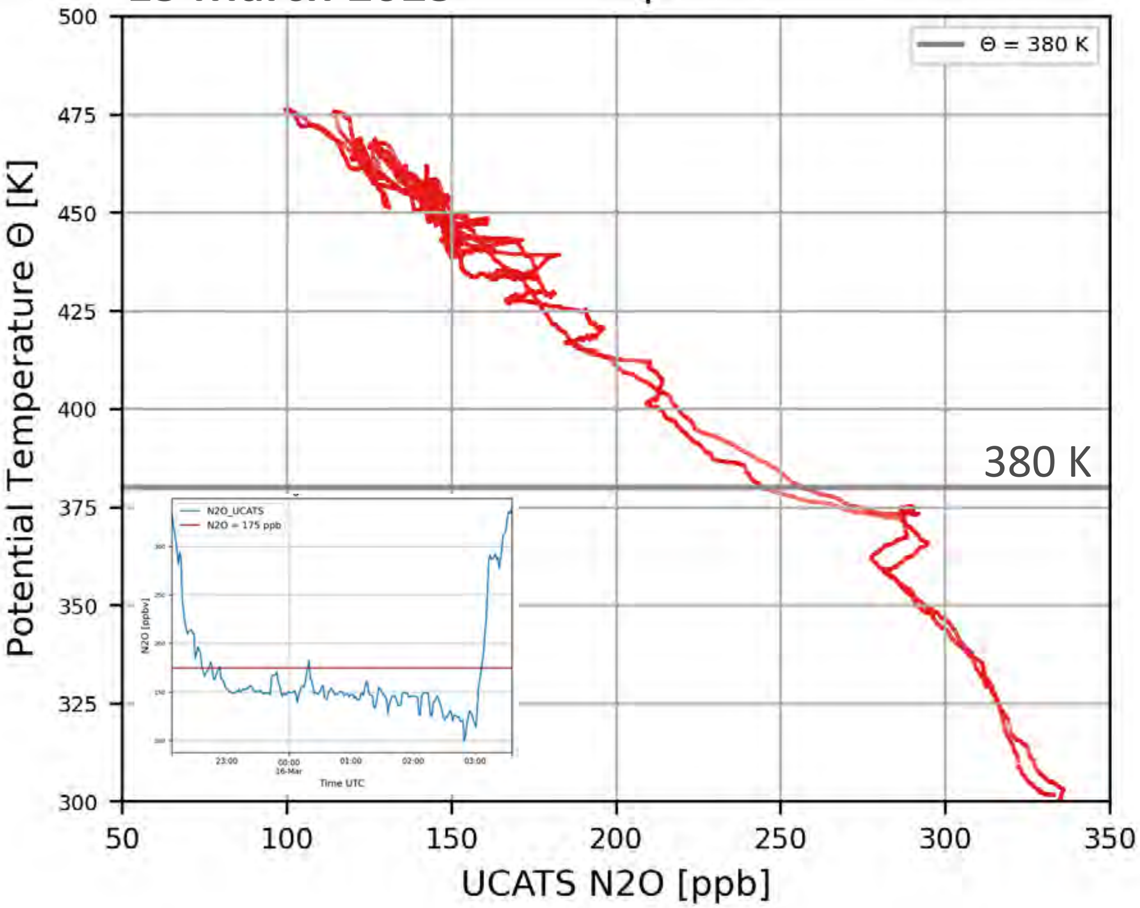

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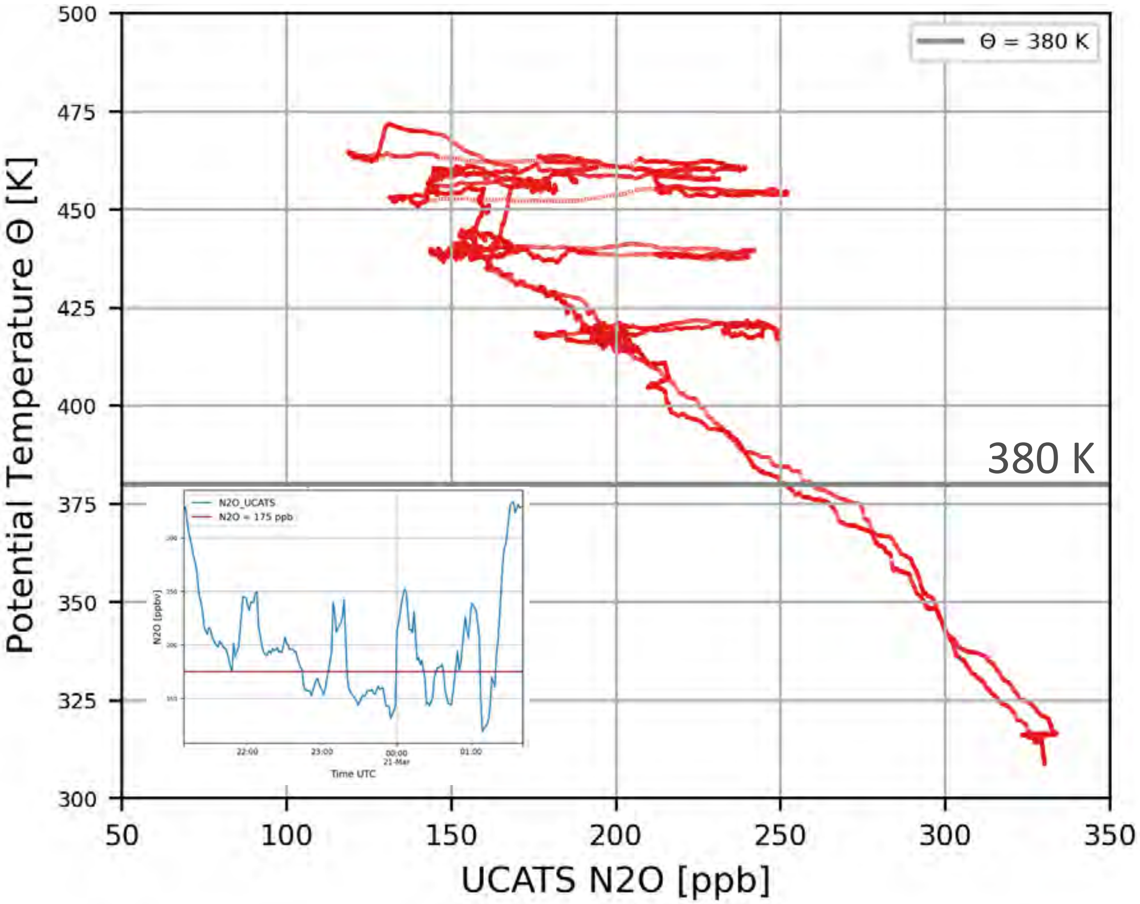

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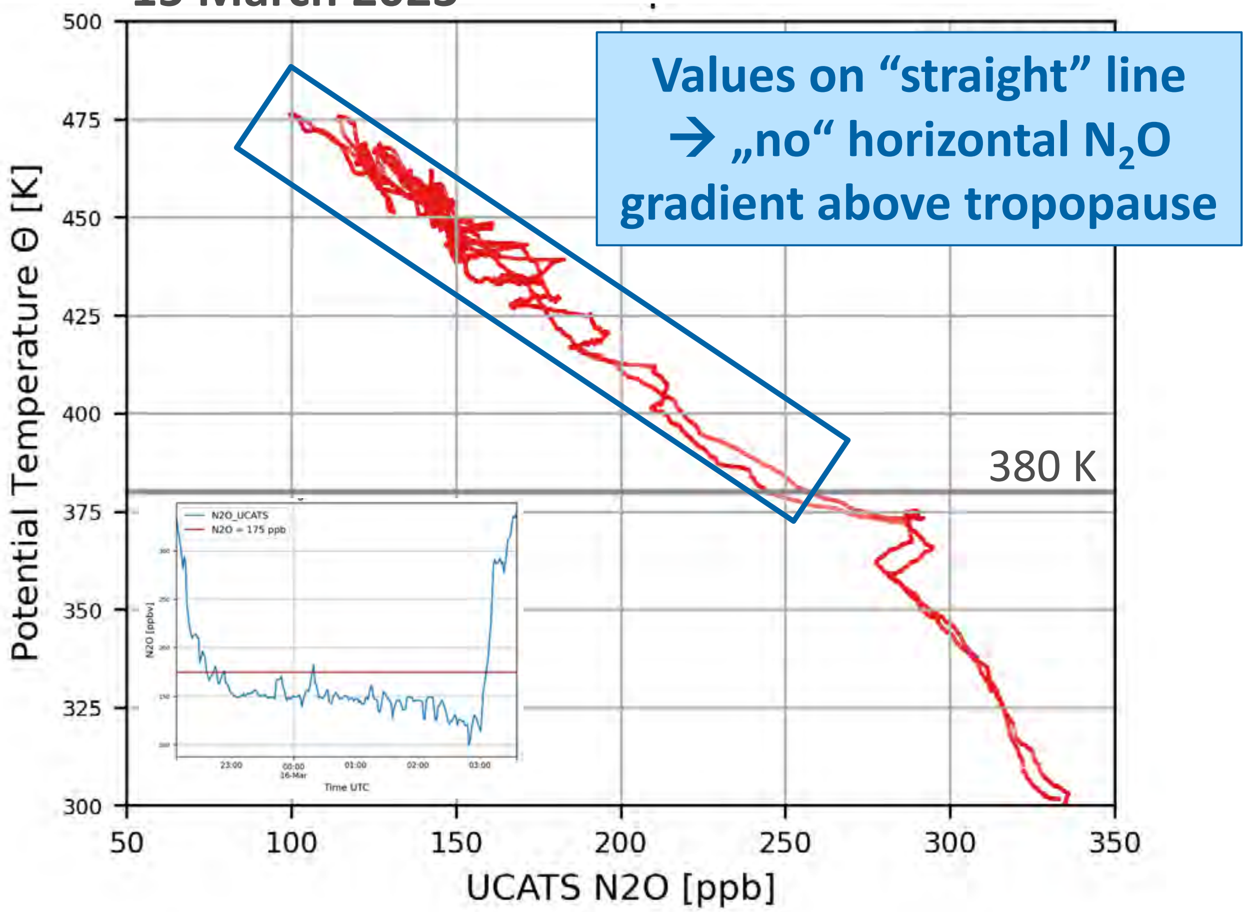

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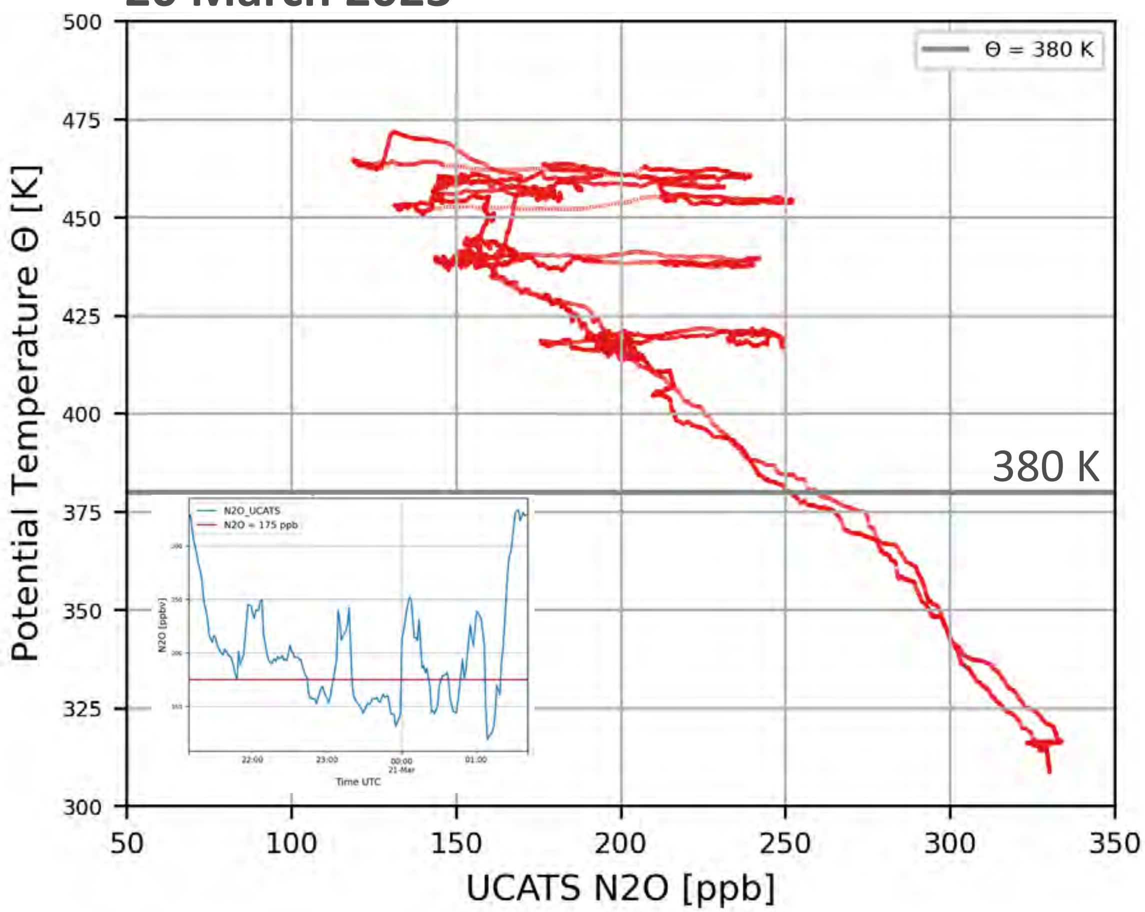

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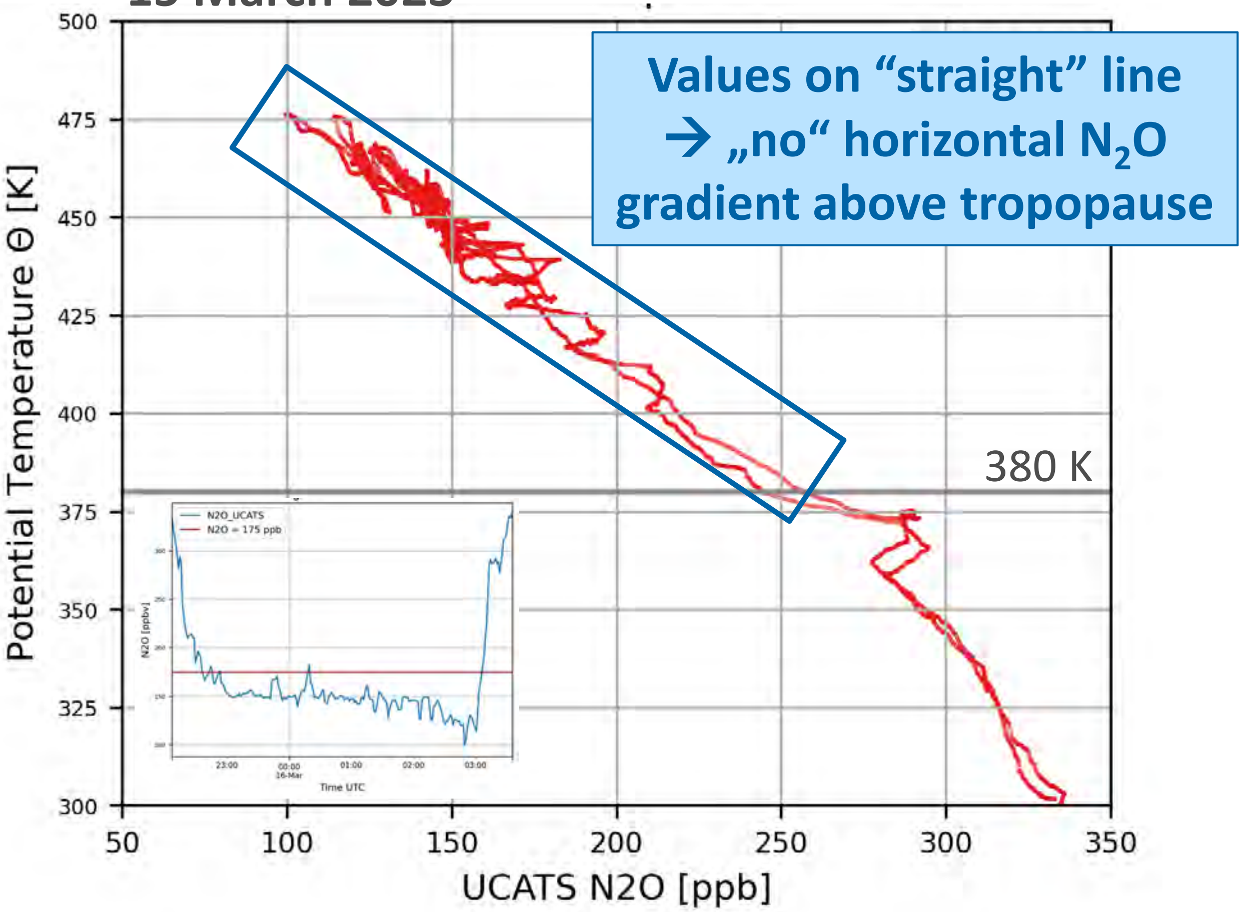

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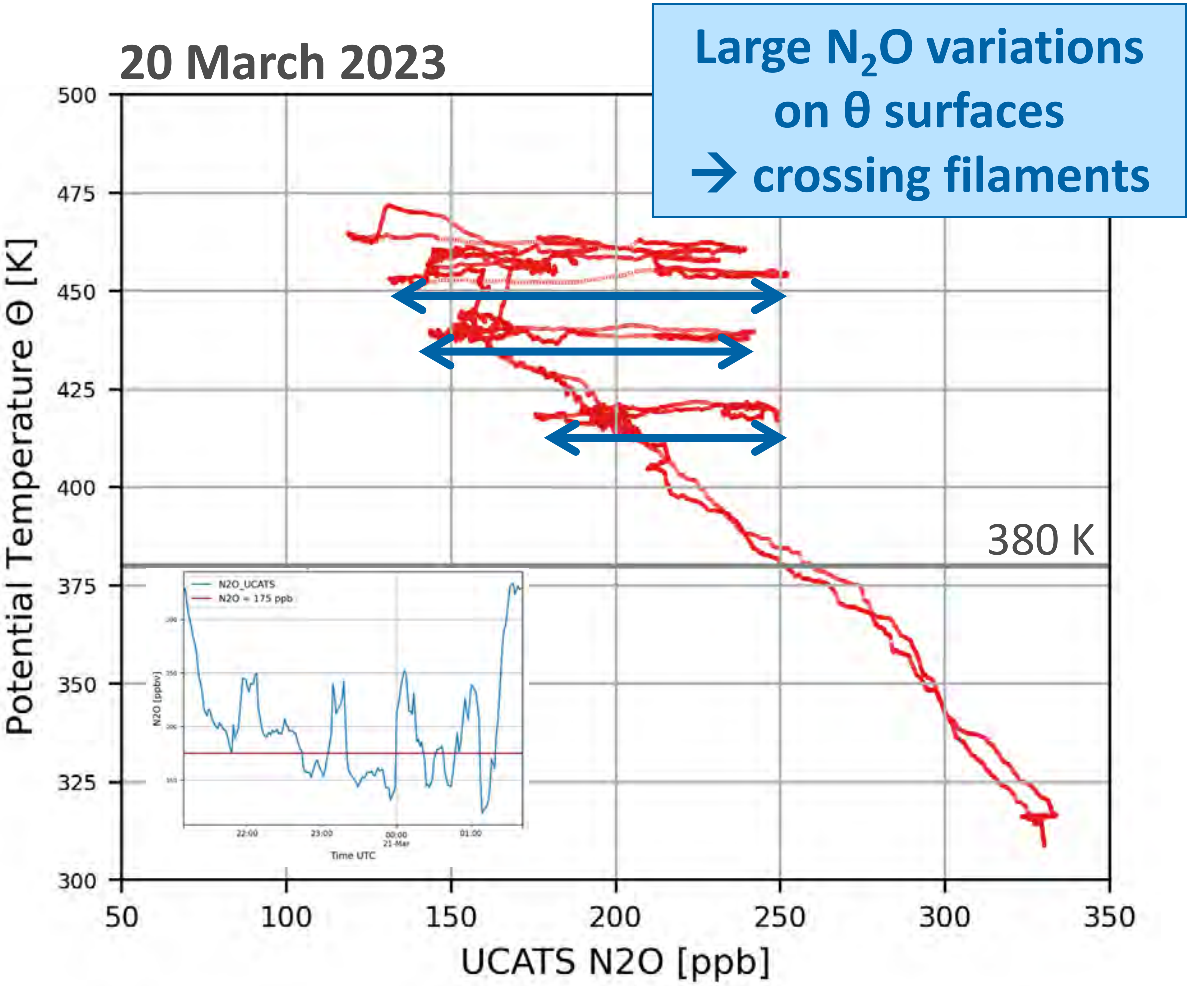

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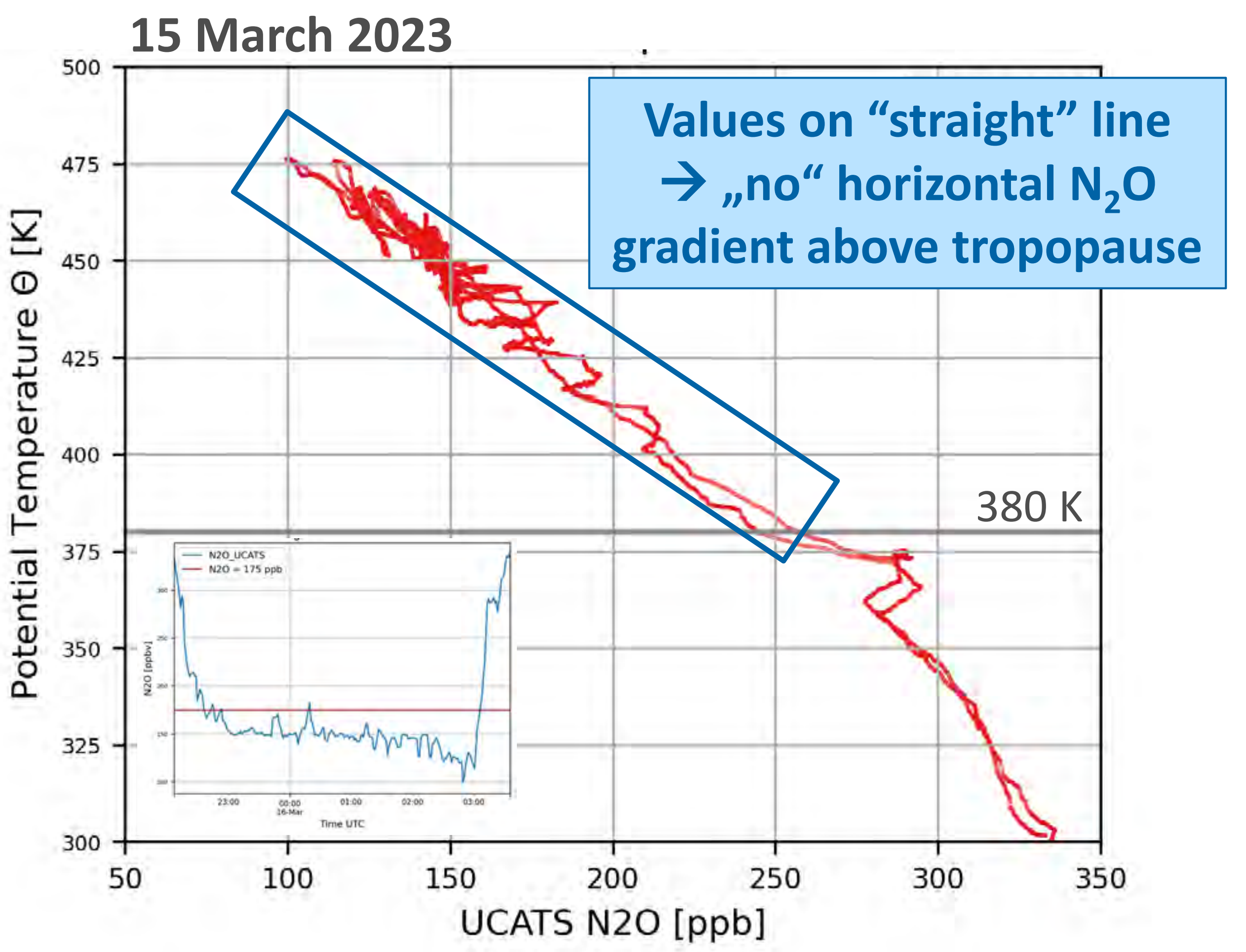
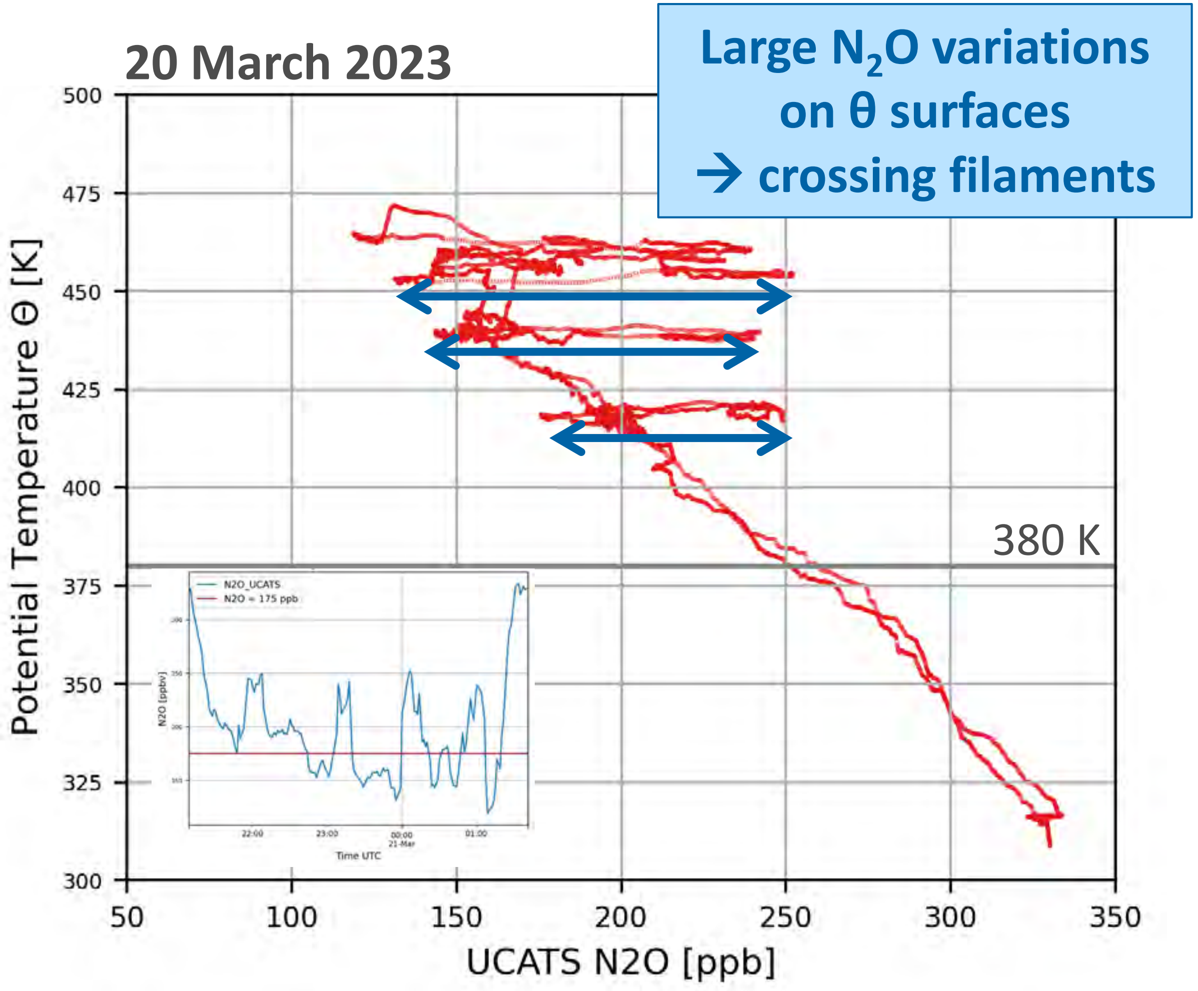




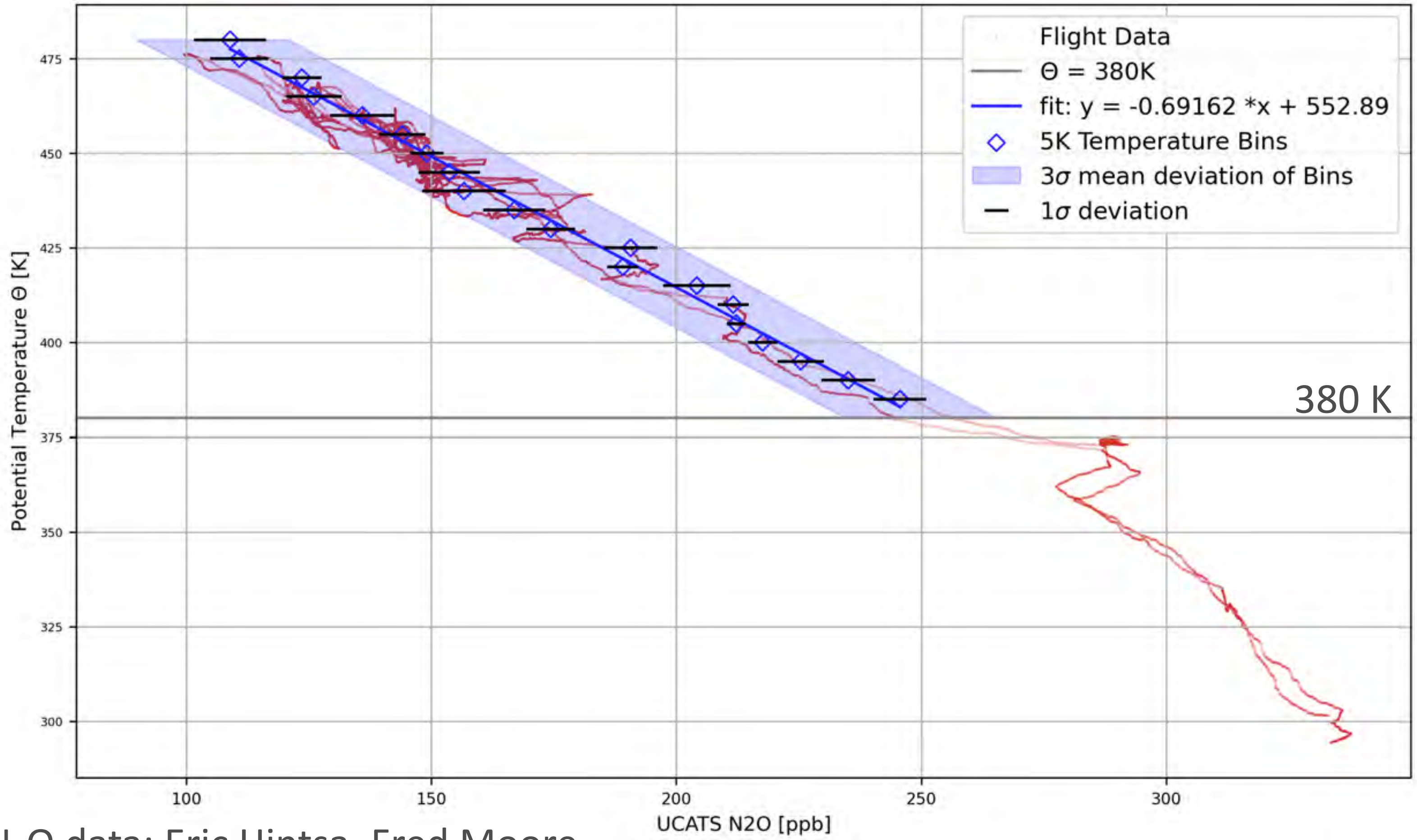
reference flight

N_2O data: Eric Hintsa, Fred Moore

F. Kuderna (Master thesis Uni Vienna, 2024)

From reference flight to N_2O_{VOR} vortex criterion

15 March 2023: linear fit



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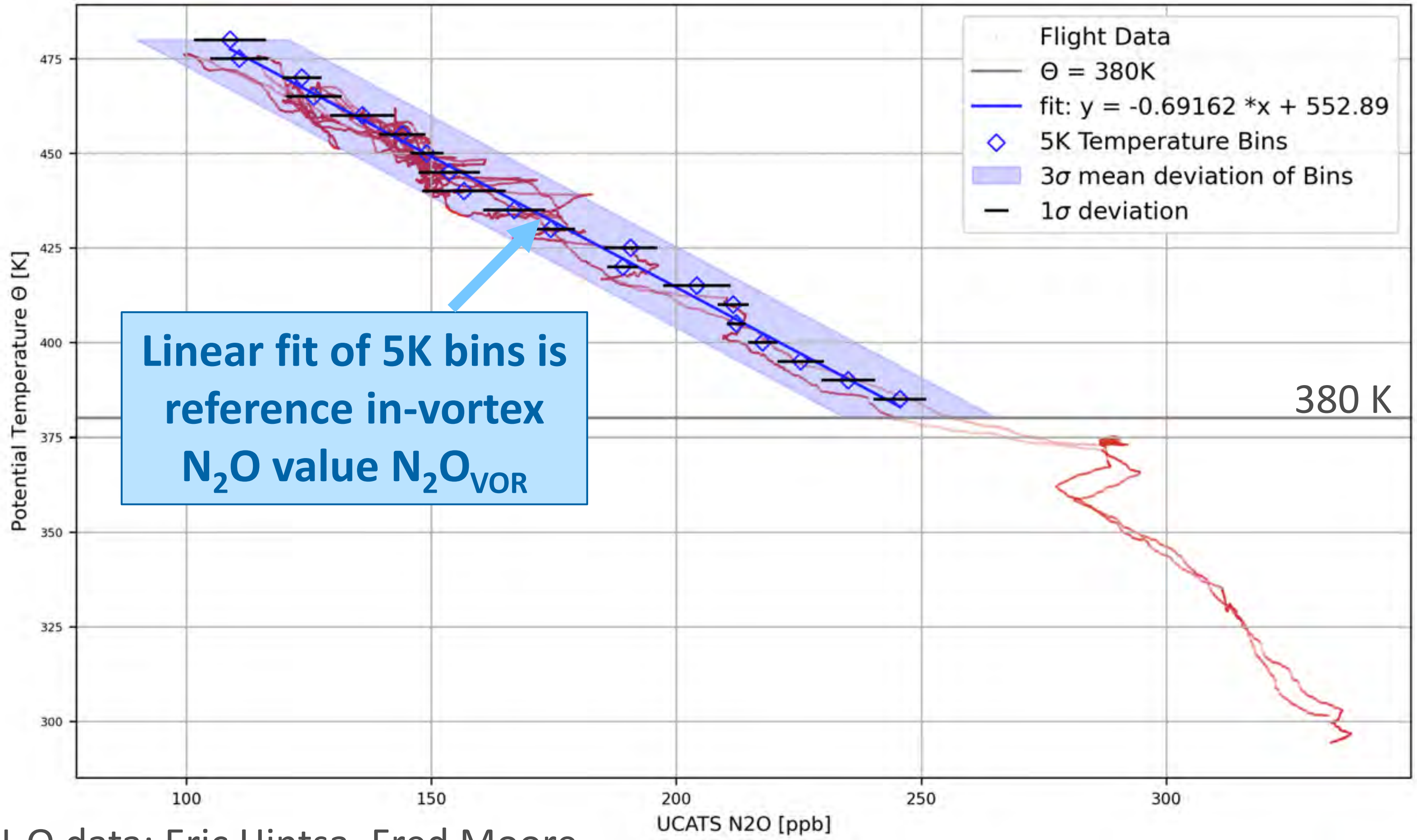

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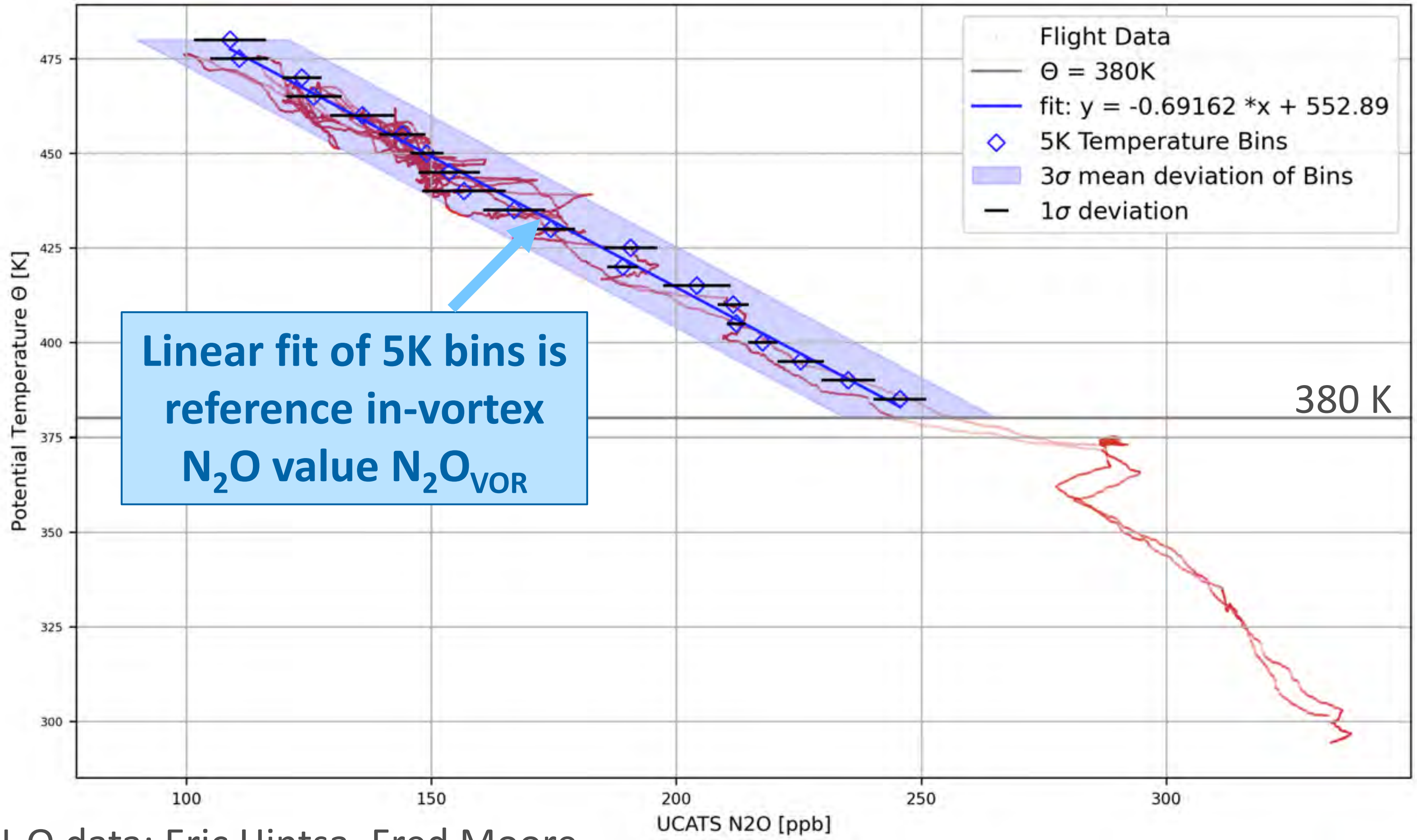

- **Horizontal error bar is 3σ with σ = mean standard deviation of N_2O in bins**
- **3σ = 15.46 ppb (Greenblatt uses 3σ = 20 ppb)**
- **N_2O_{VOR} ± cutoff defines in-vortex criterion for all other flight datapoints (blue area)**

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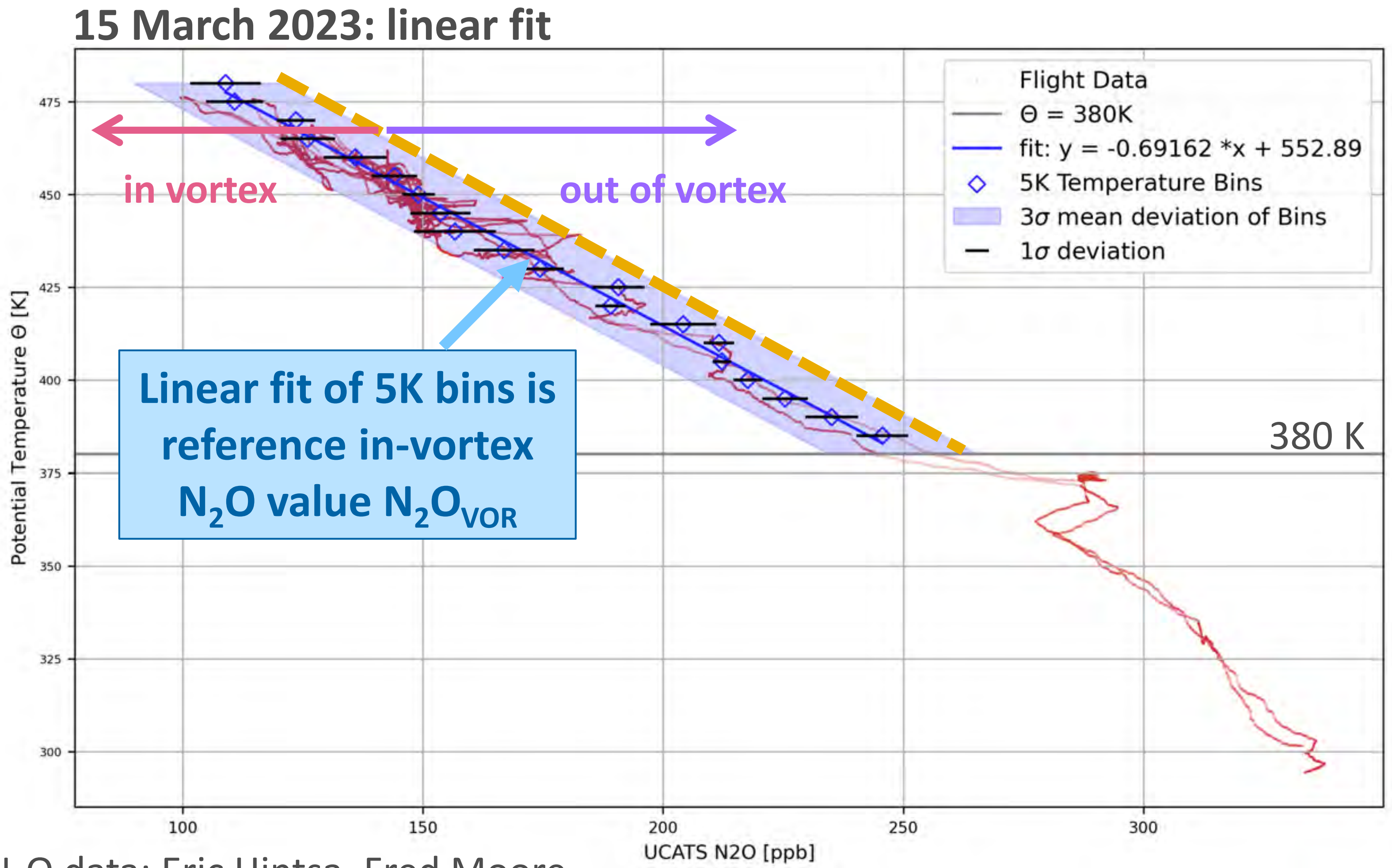

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Reference Flight: 15.3.2023

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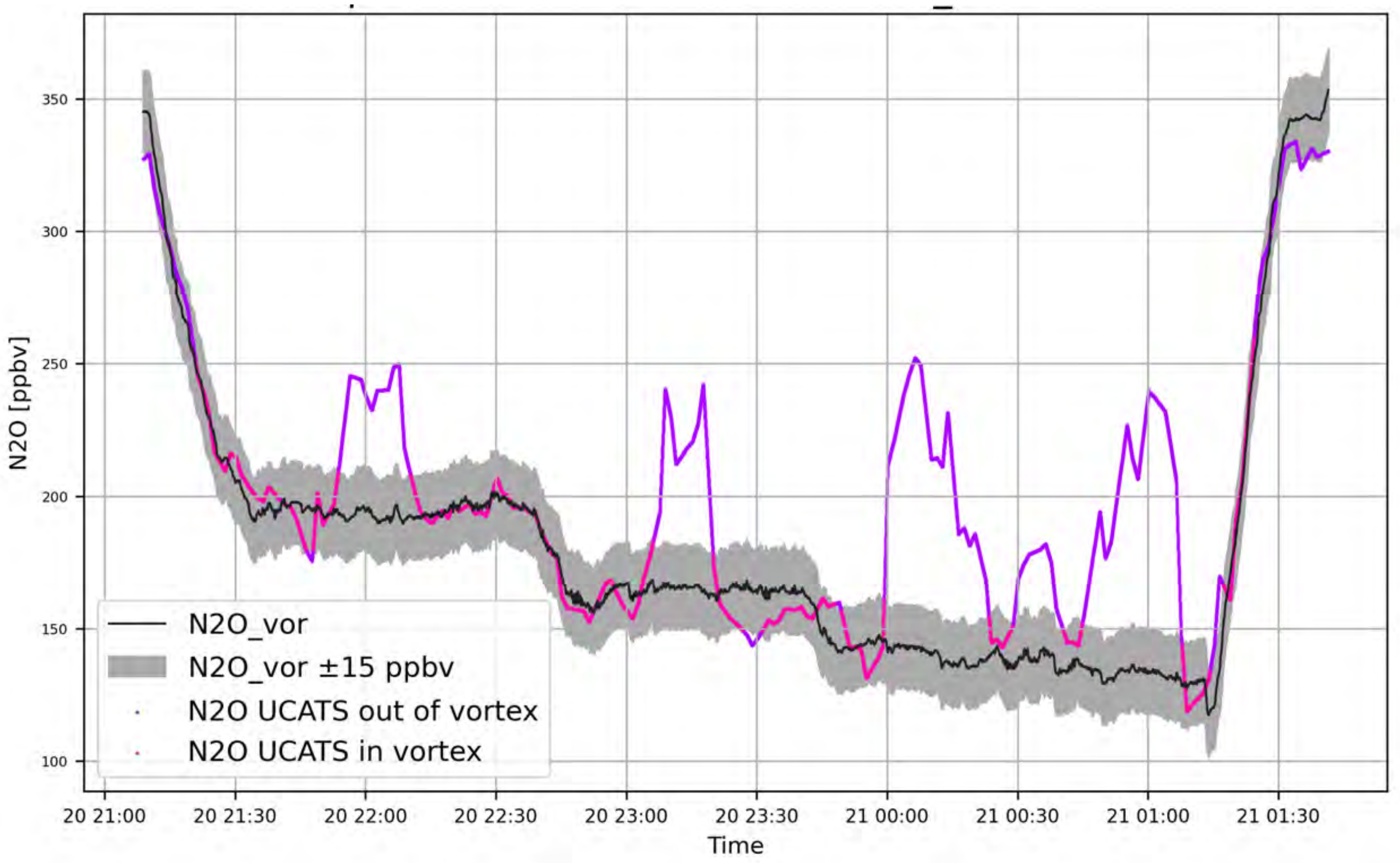
→ The assumption of 1 reference flight for analyzing the entire campaign is justified

Test of vortex flag with the flight on 20 March 2023



N_2O data: Eric Hintsa, Fred Moore

- **Calculate:** **$|N_2O - N_2O_{VOR}| <$ cutoff**

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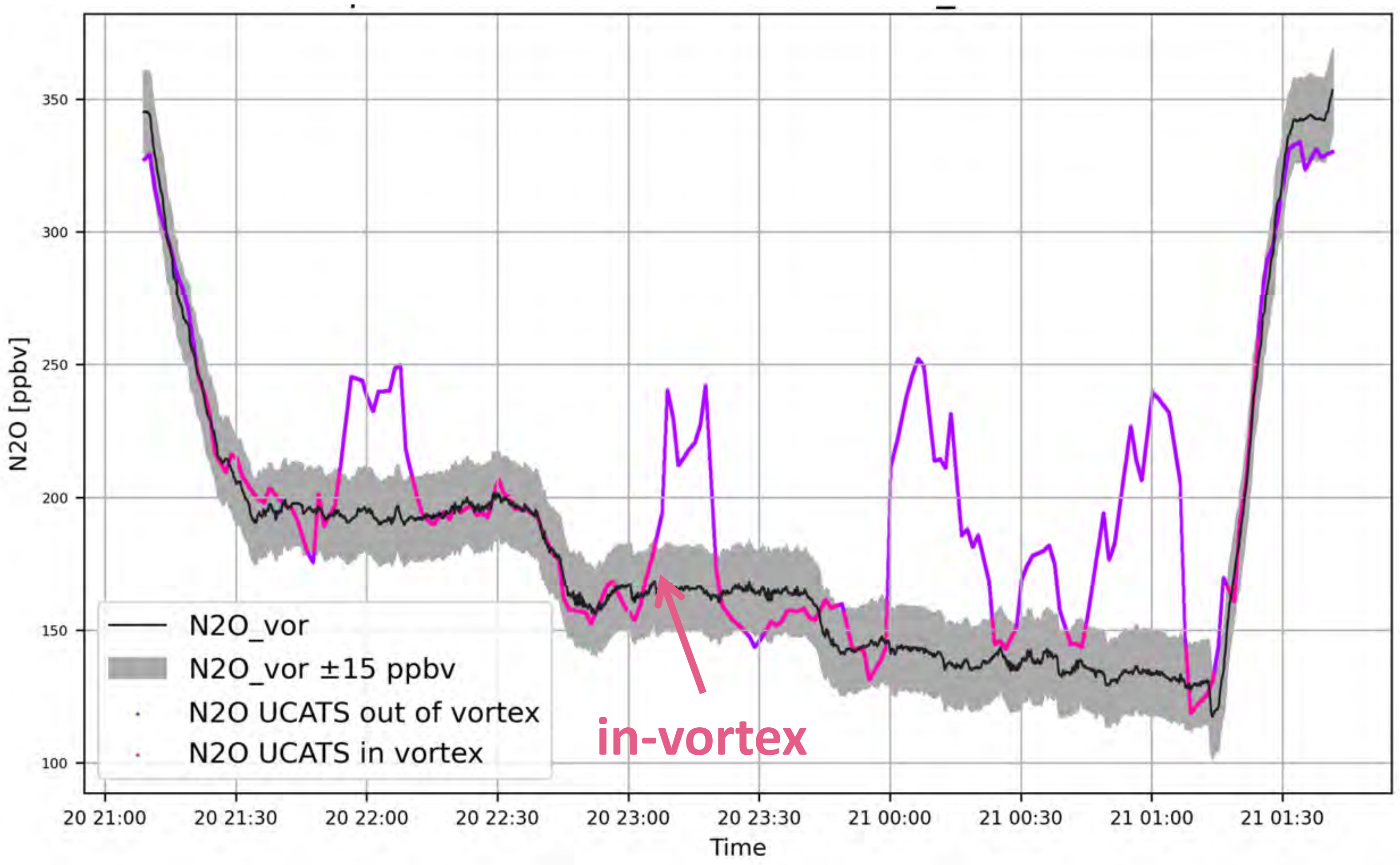

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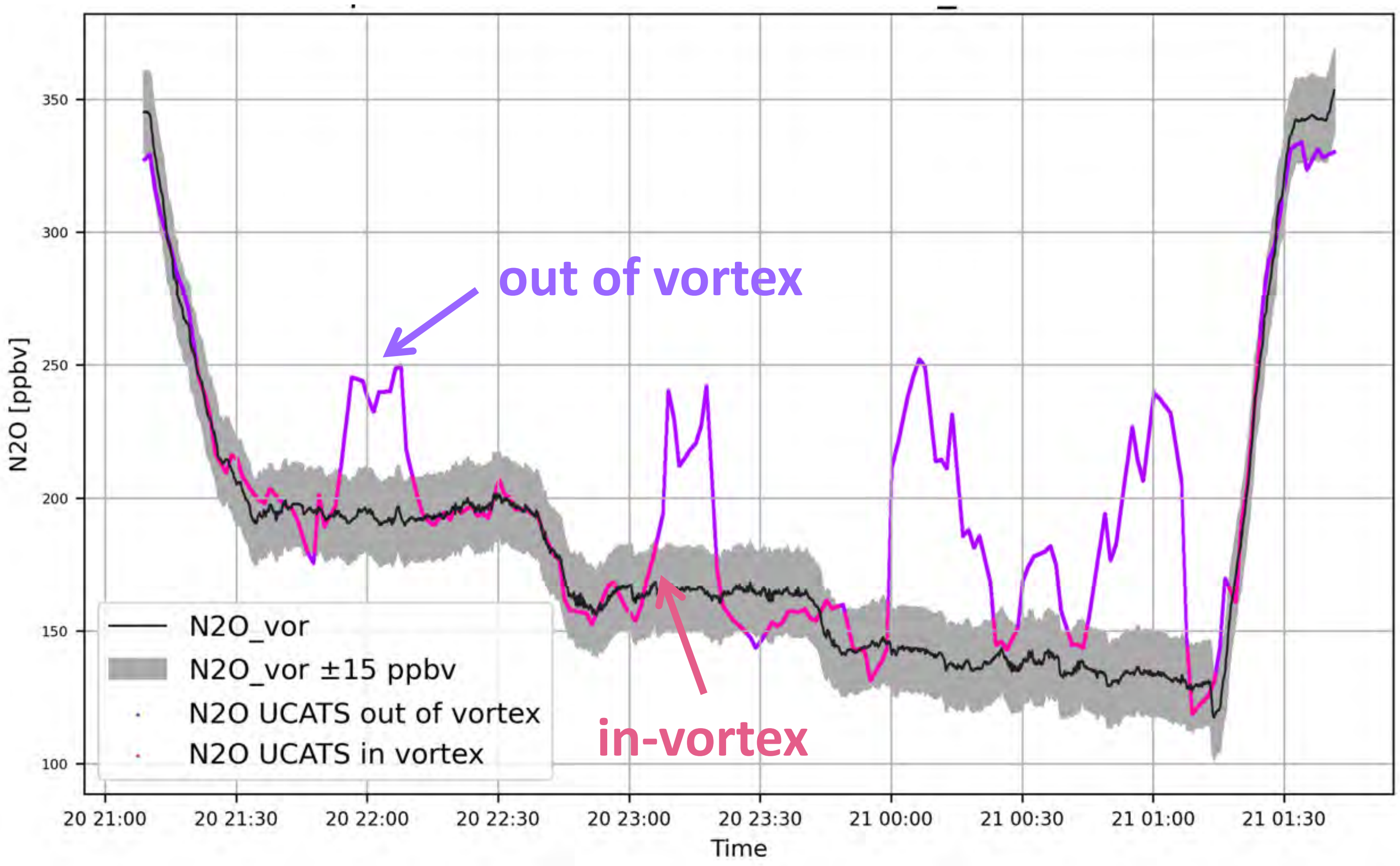

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- **Calculate:** **$|N_2O - N_2O_{VOR}| < \text{cutoff}$**
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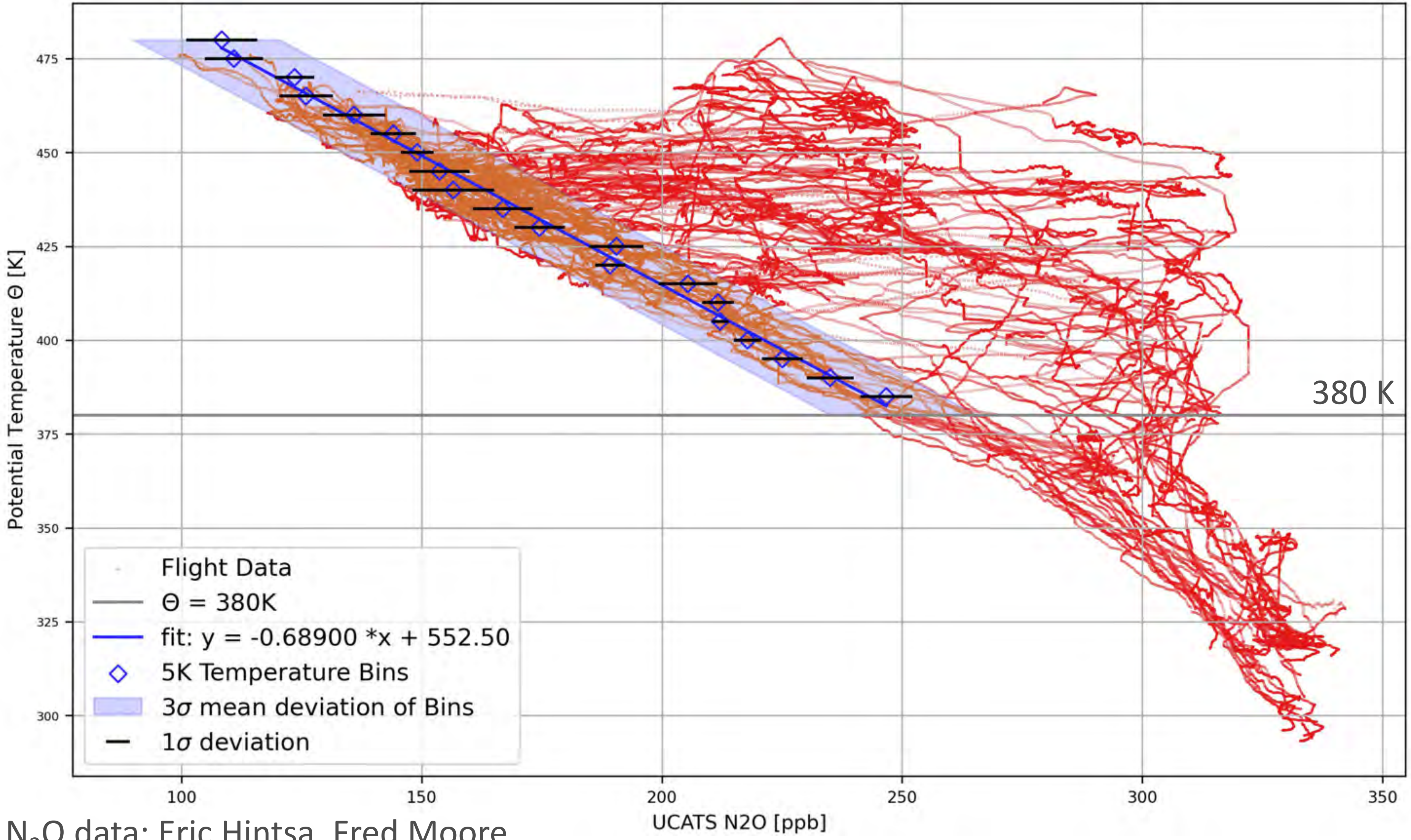
- **If False: data point not in vortex**

Application of vortex flag to all SABRE flights



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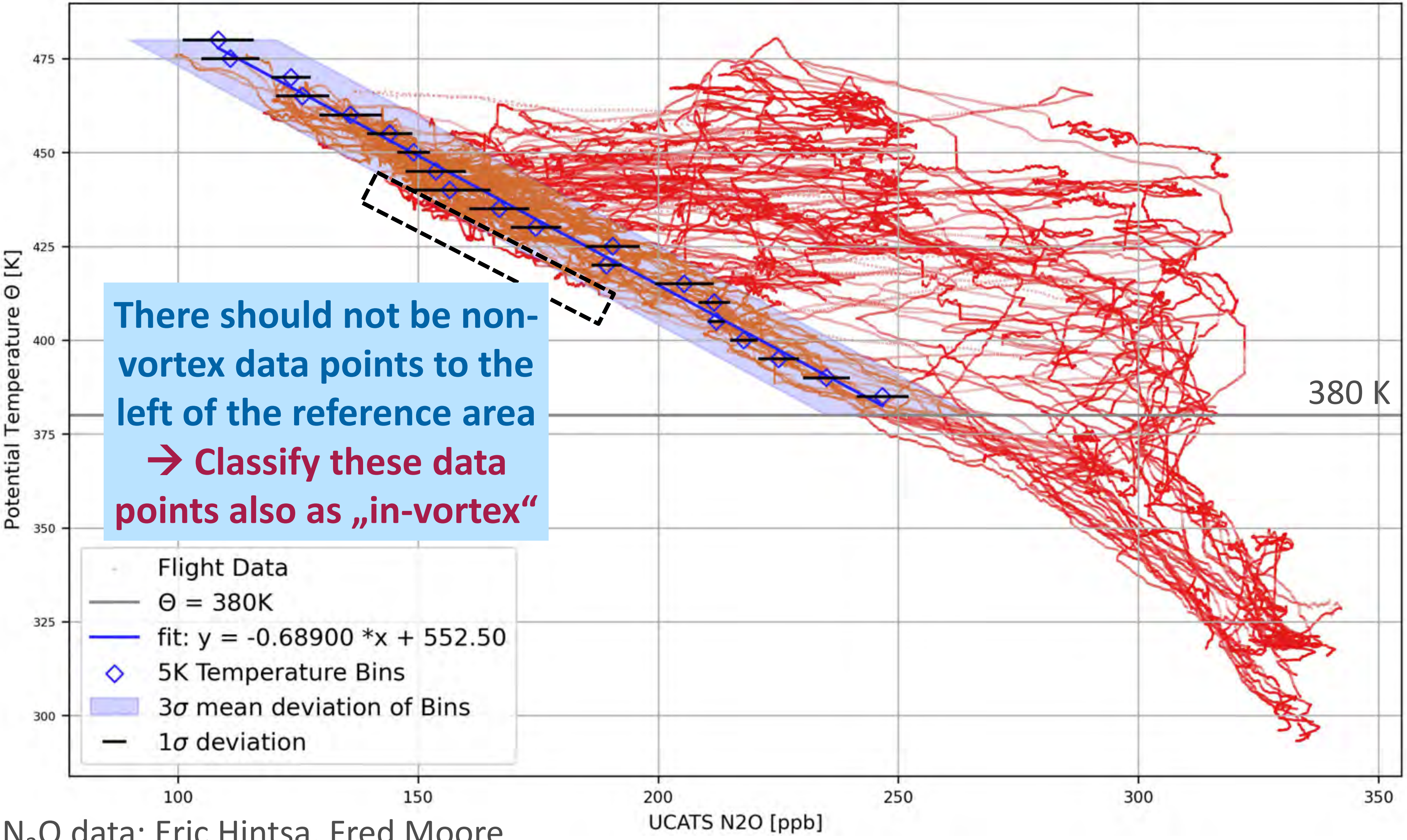

N_2O data: Eric Hintsa, Fred Moore

How consistent is the vortex flag with „age of air“ calculations?

N_2O data: Eric Hintsa, Fred Moore
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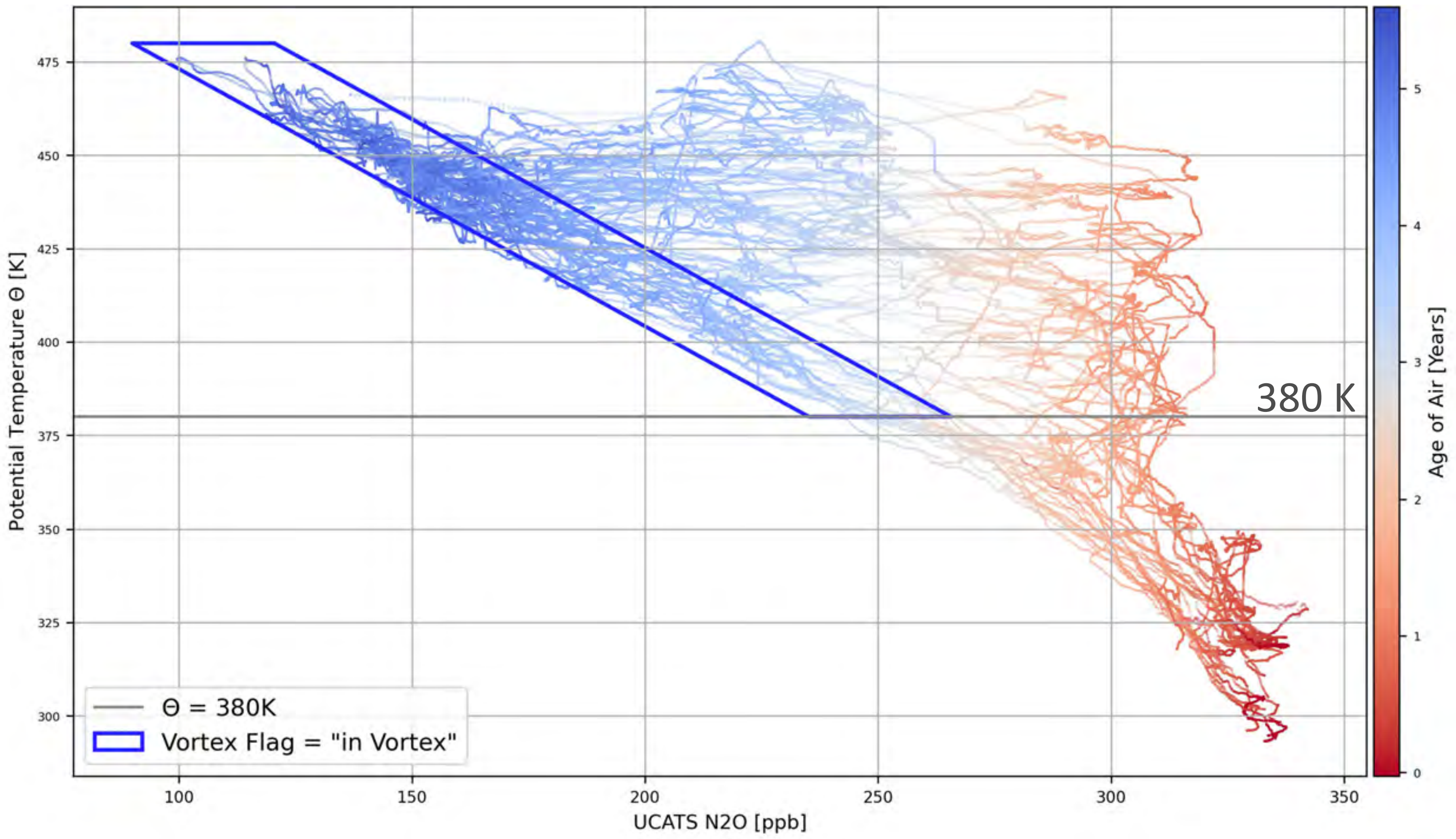

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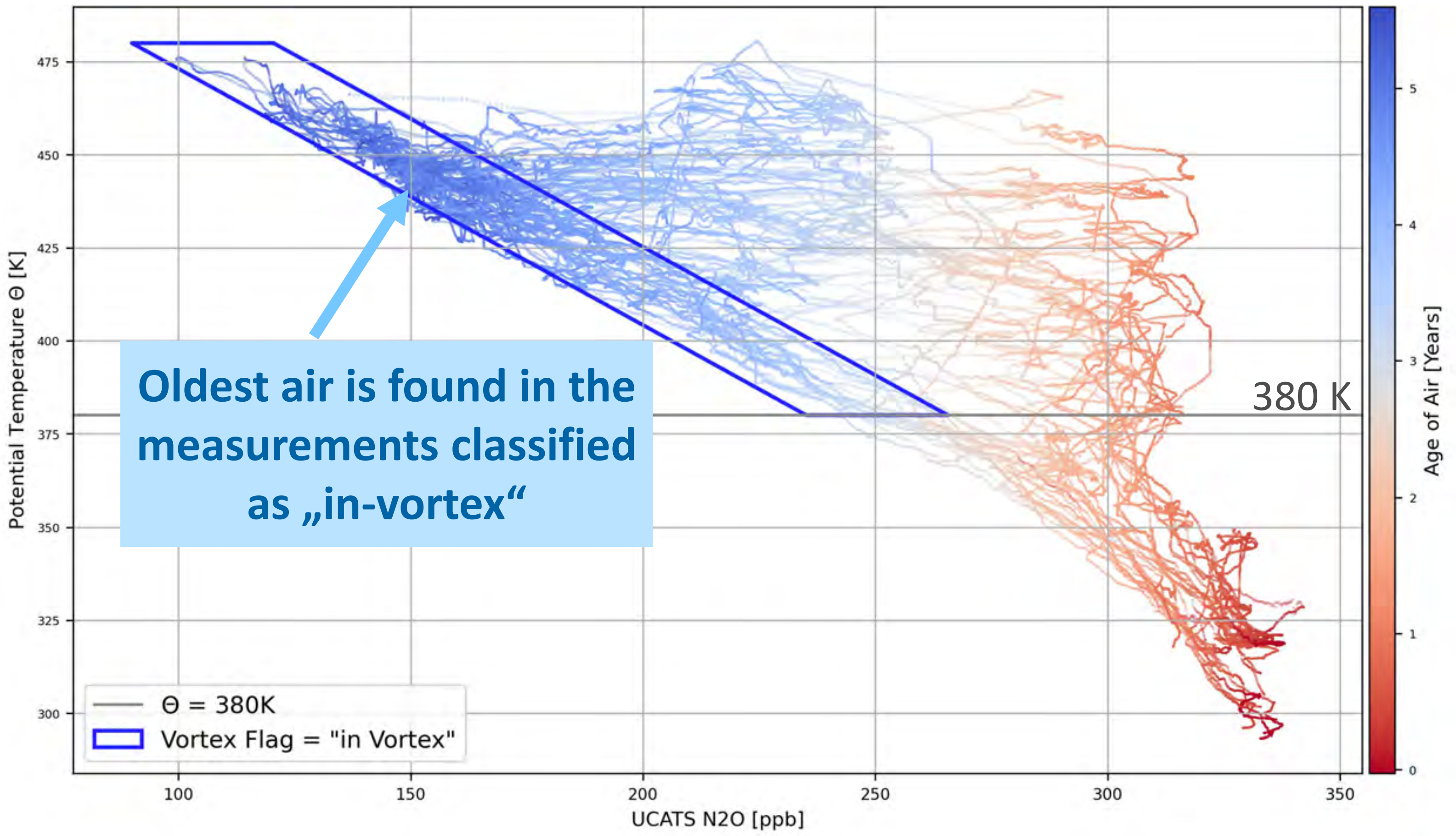

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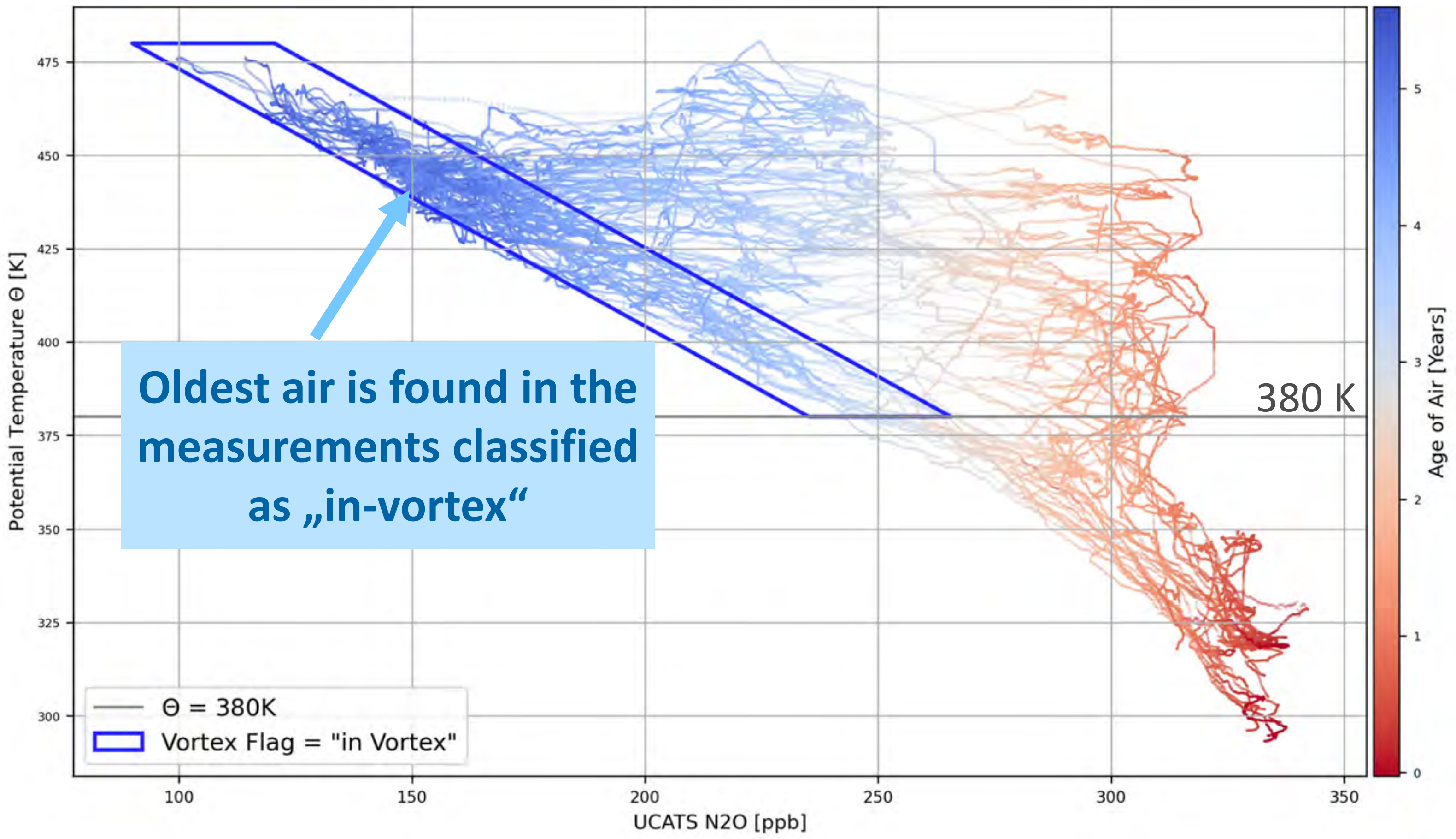
Good agreement between „age of air“ and vortex flag

How consistent is the vortex flag with „age of air“ calculations?

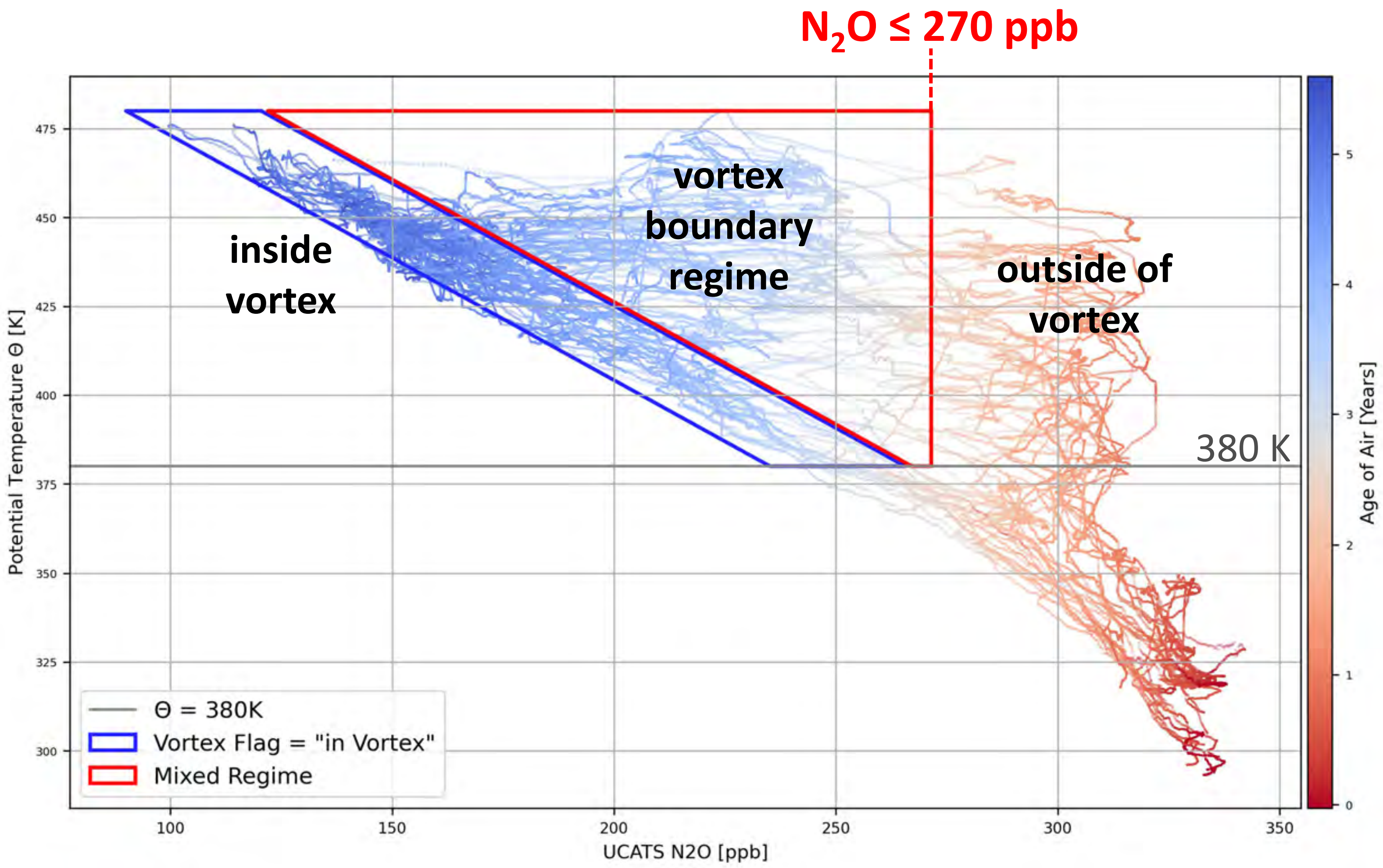


Is two regimes (in-vortex, outside vortex) sufficient?

N_2O data: Eric Hintsa, Fred Moore
Age of air data: Eric Ray

Good agreement between „age of air“ and vortex flag

Definition of three regimes



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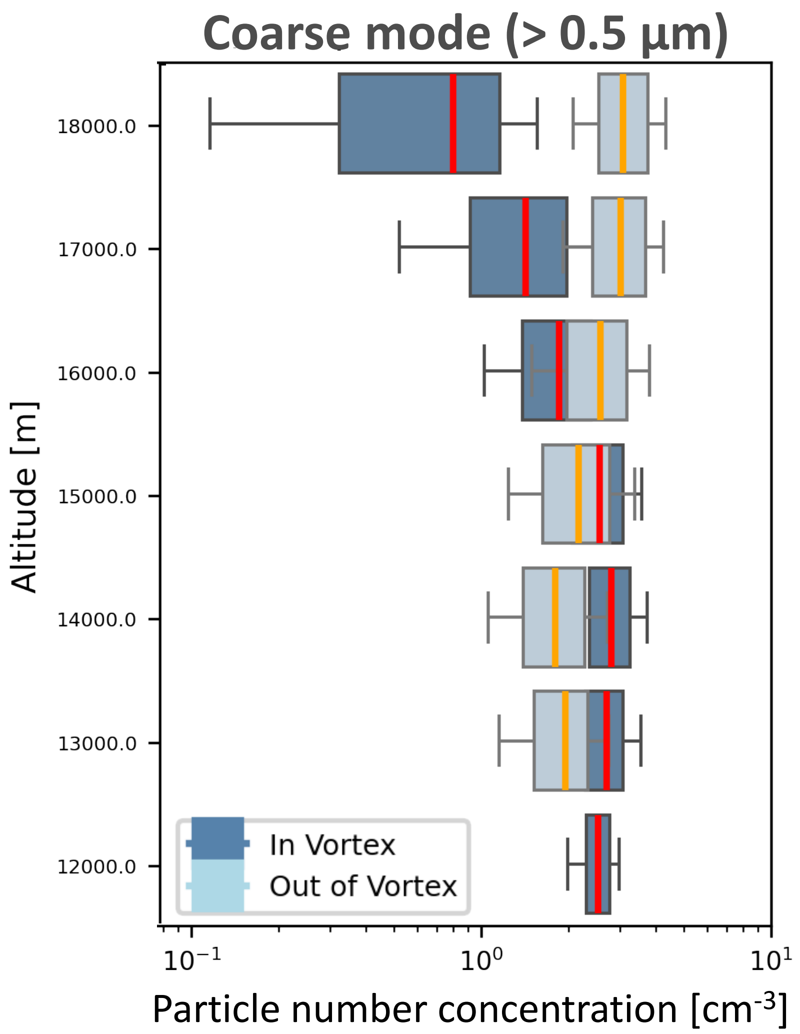
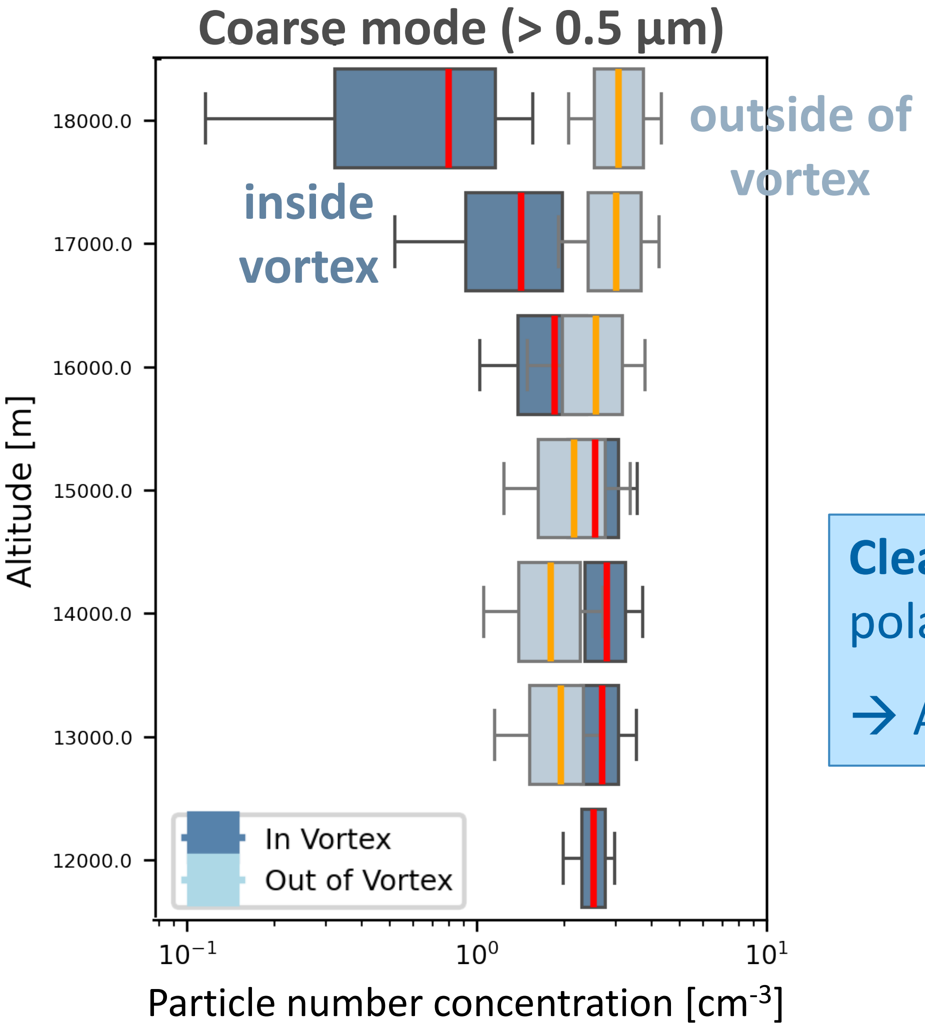
Coarse mode number concentration inside and outside of the polar vortex: D_p > 0.5 µm



F. Kuderna (Master thesis Uni Vienna, 2024)

Coarse mode number concentration inside and outside of the polar vortex: $D_p > 0.5$ µm



Clear differences between airmasses inside and outside the polar vortex:

→ Above ~16 km altitude: particles > 0.5 µm depleted in vortex

F. Kuderna (Master thesis Uni Vienna, 2024)

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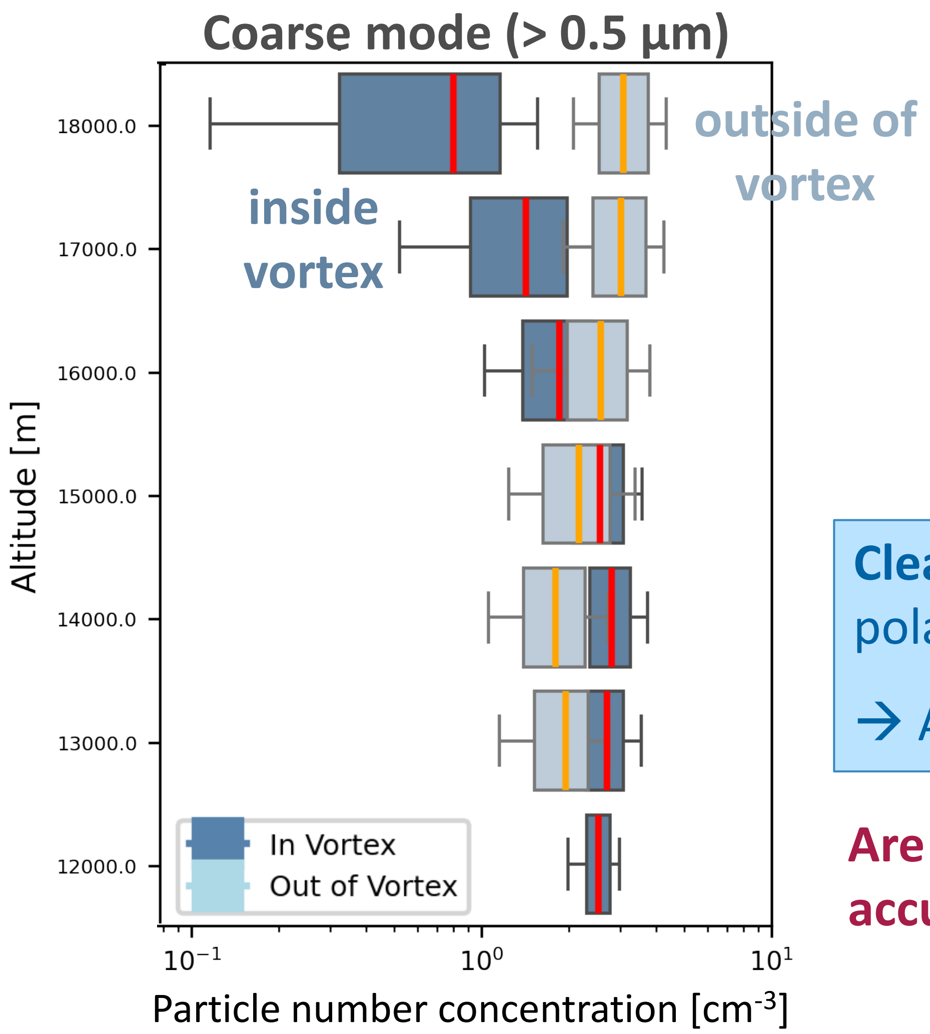

Clear differences between airmasses inside and outside the polar vortex:

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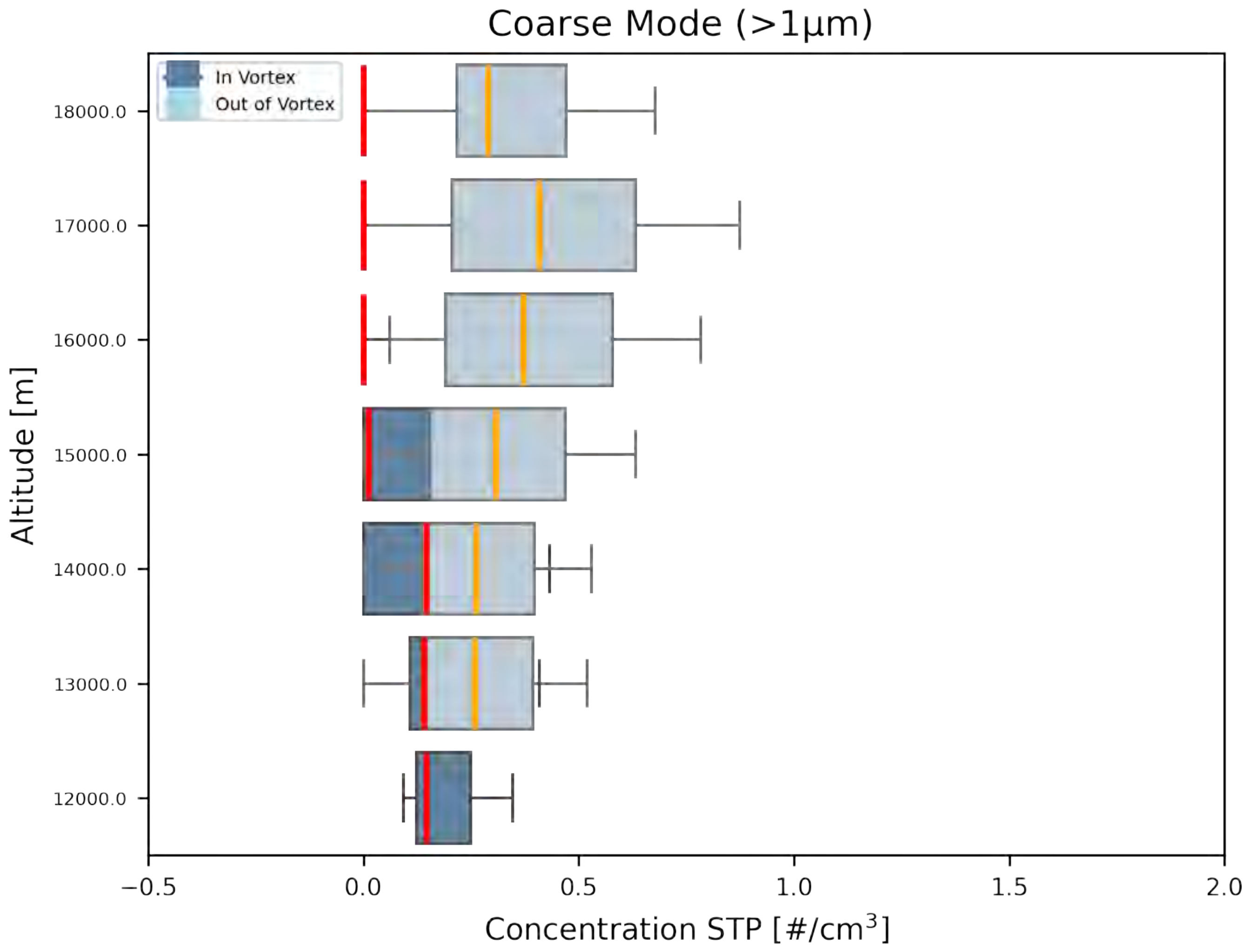
Are the observed coarse mode particles „the tale" of the accumulation mode (0.1-1 µm) or do we also see larger particles?

F. Kuderna (Master thesis Uni Vienna, 2024)

Coarse mode number concentration inside and out of the polar vortex: $D_p > 1\ \mu m$



F. Kuderna (Master thesis Uni Vienna, 2024)

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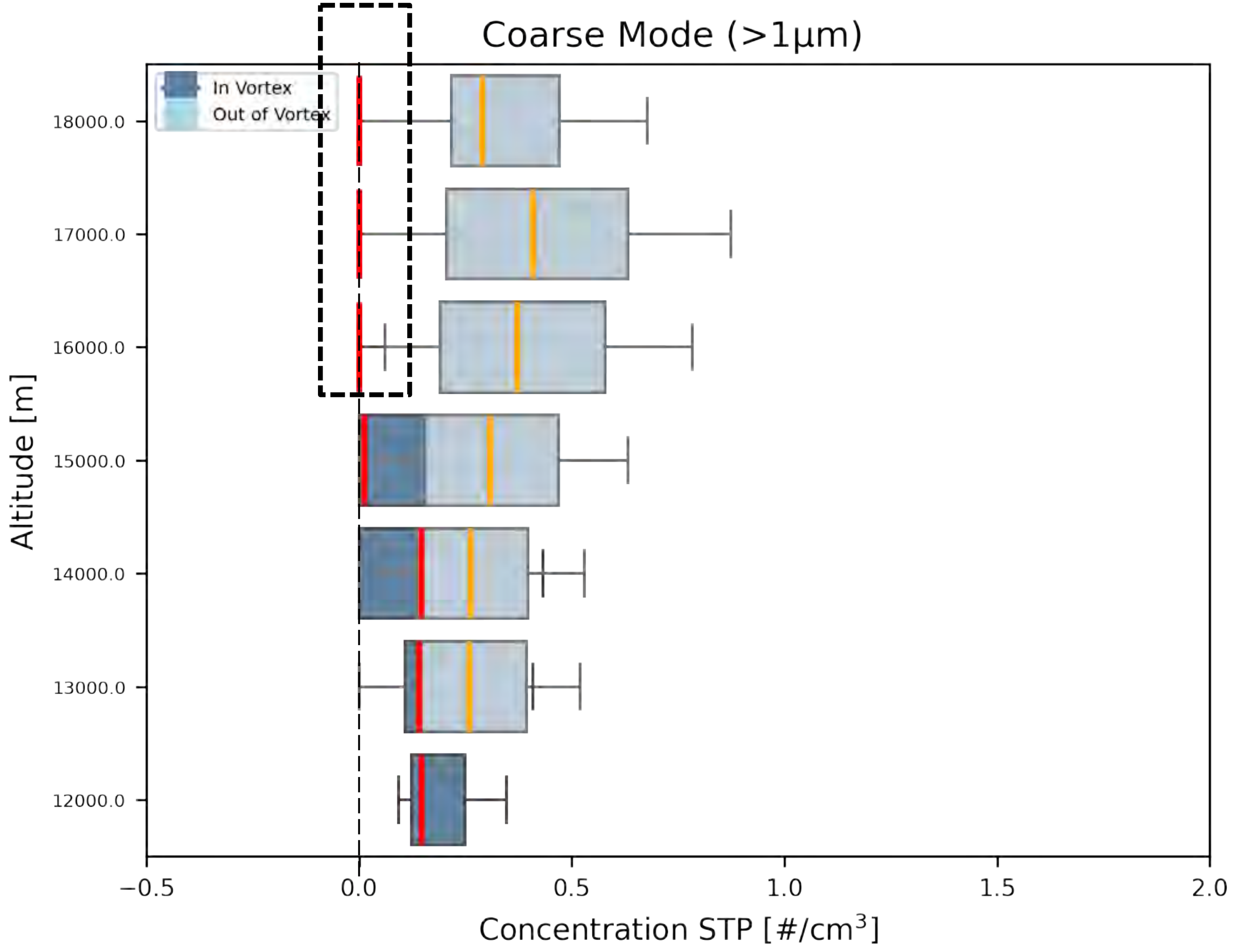


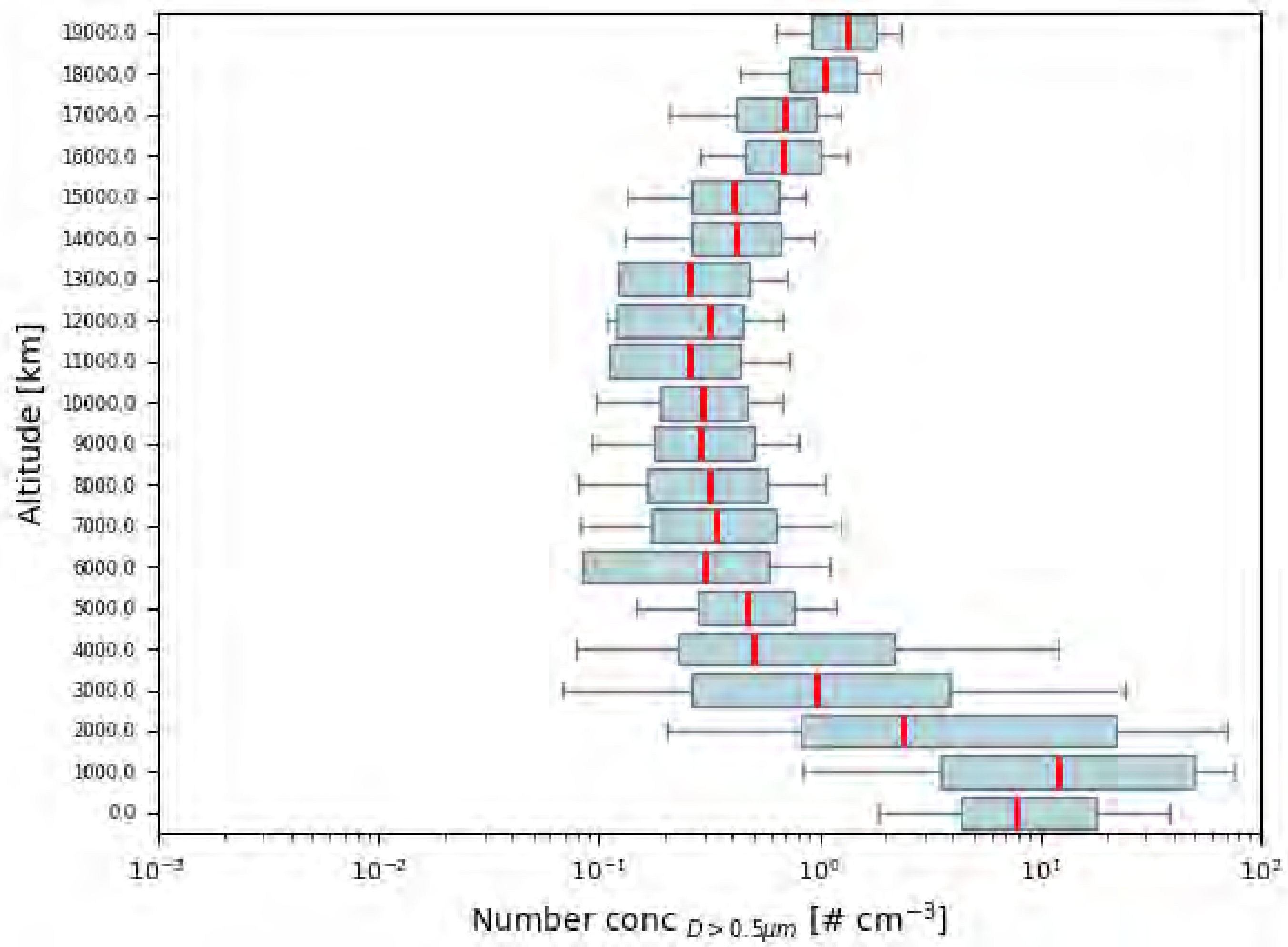
→ **Median coarse mode concentration in-vortex: almost no particles > 1 µm above ~ 16 km inside the vortex**

→ **Some coarse particles > 1 µm outside vortex**

F. Kuderna (Master thesis Uni Vienna, 2024)

Outlook on ACCLIP analyses

Vertical profile of coarse mode (> 0.5 µm) number concentration during ACCLIP 2022



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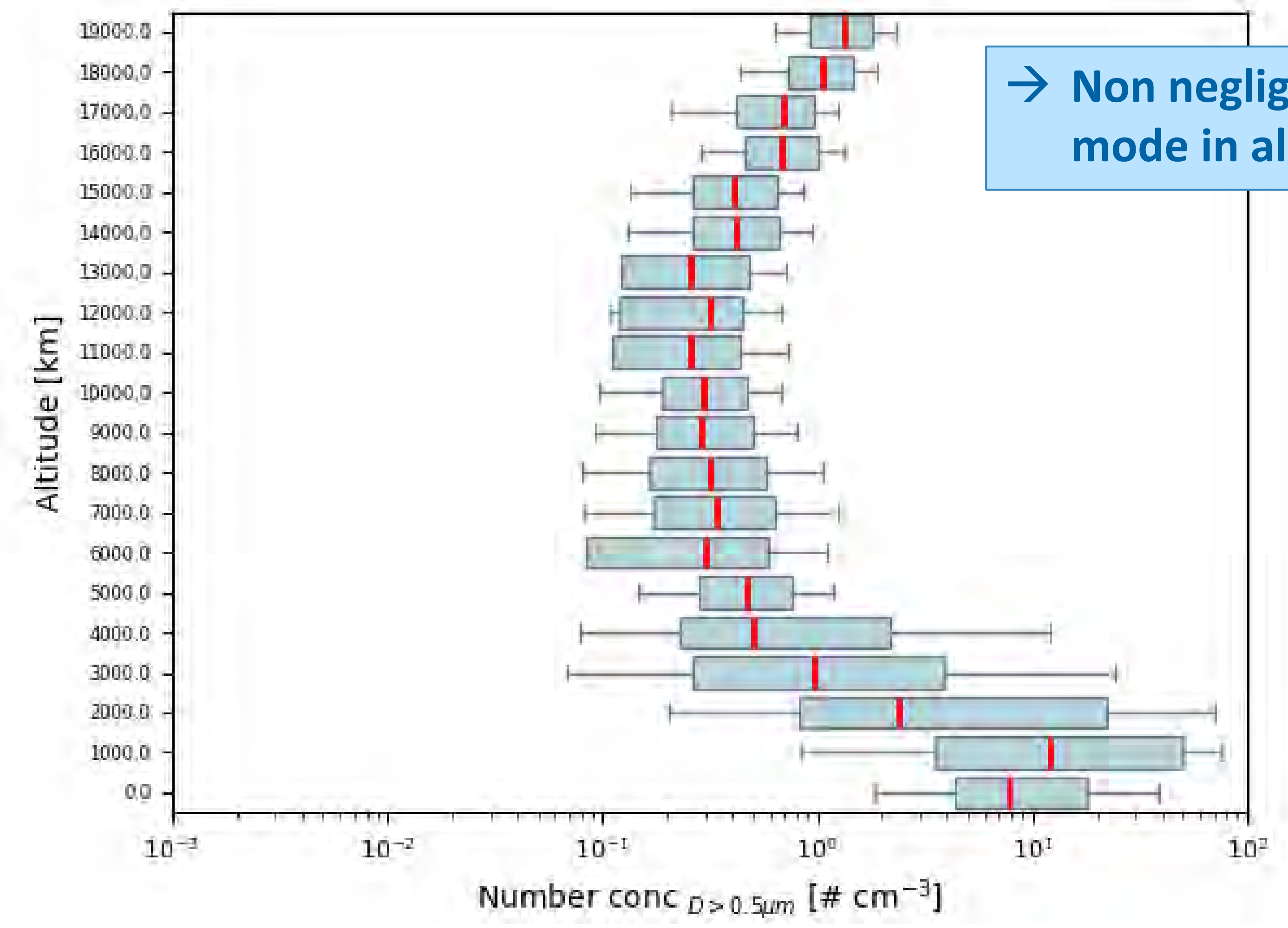
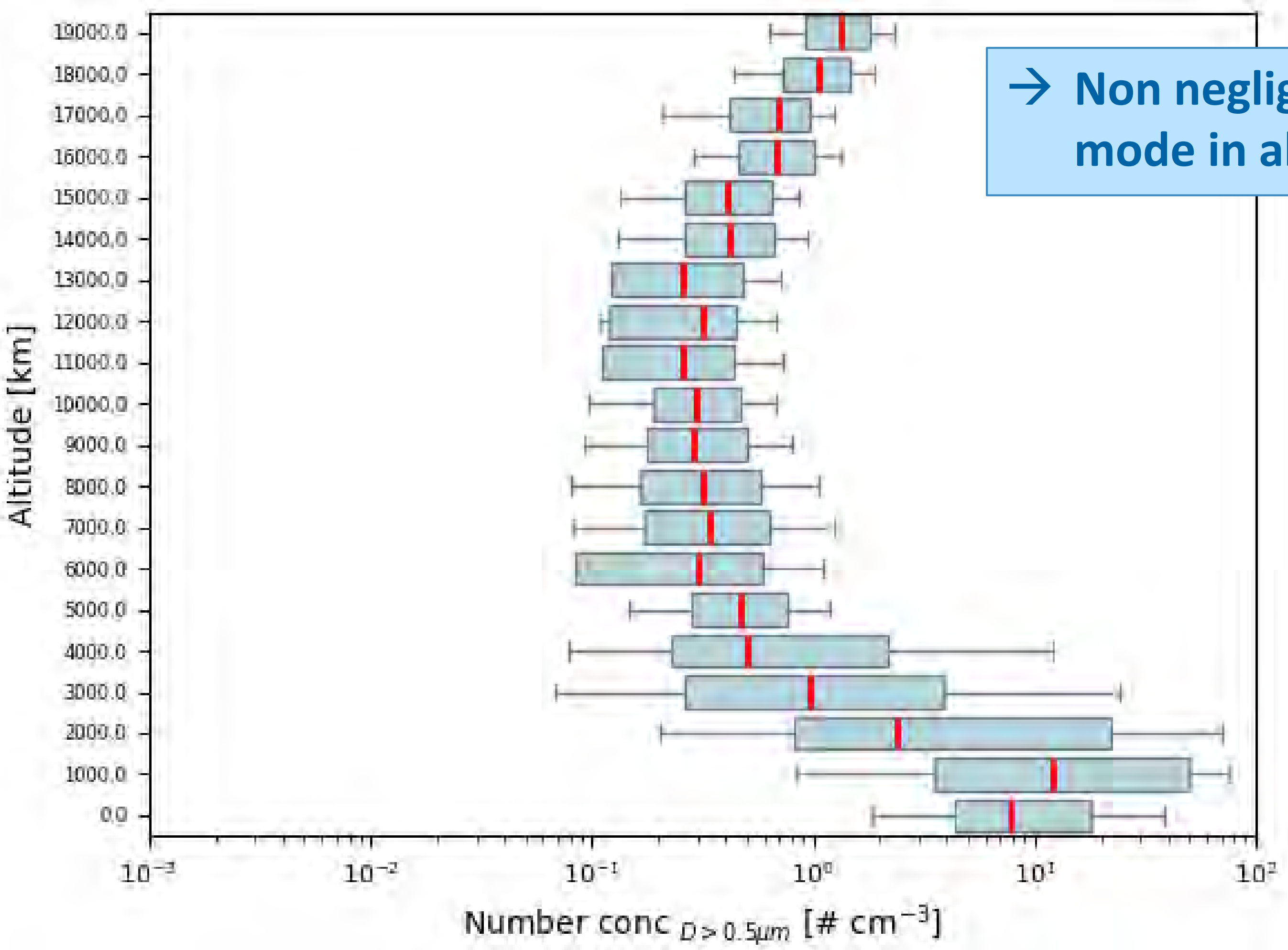


→ **Non negligible coarse mode in all ACCLIP flights**

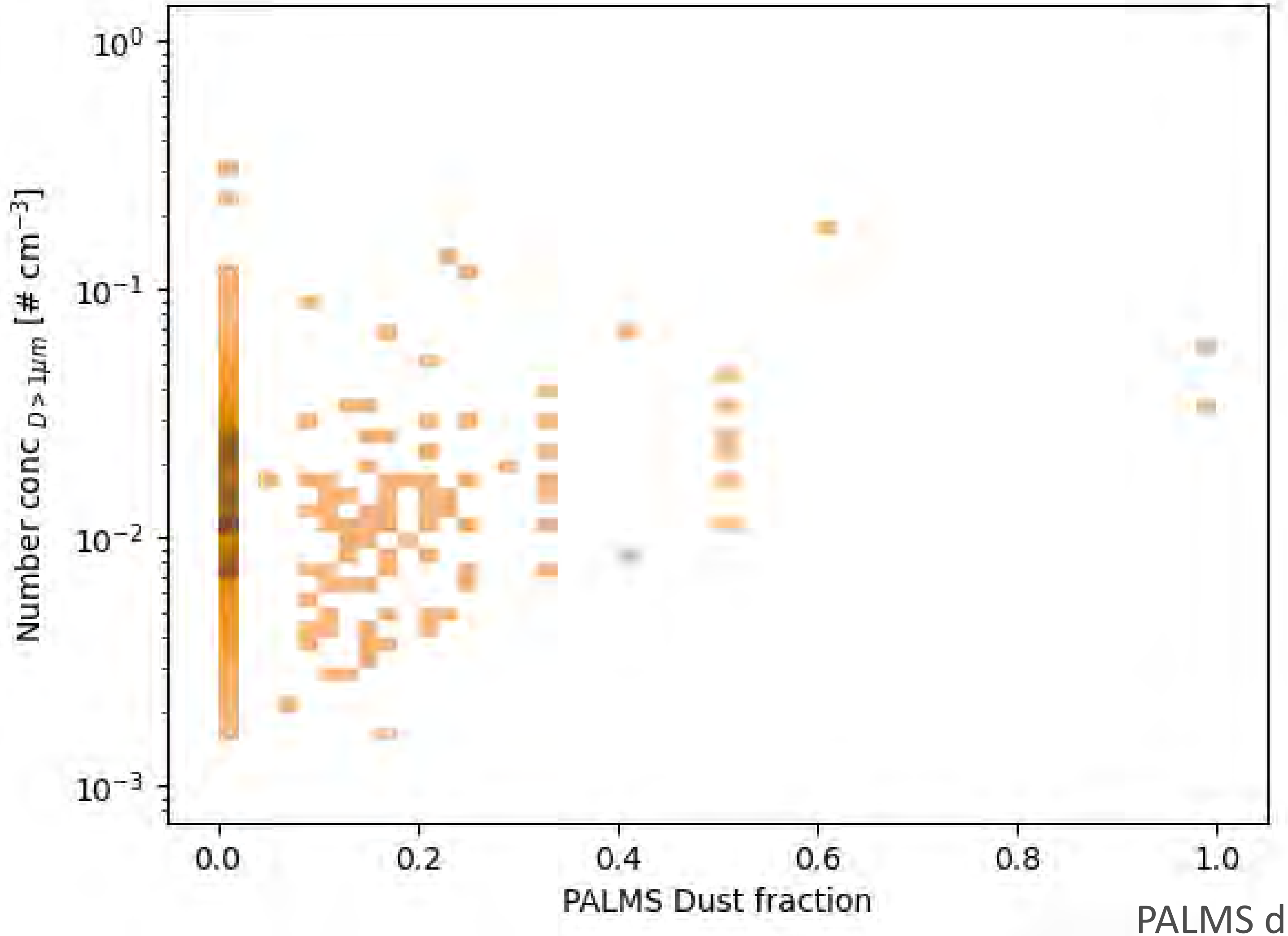
Vertical profile of coarse mode (> 0.5 µm) number concentration during ACCLIP 2022



→ **Non negligible coarse mode in all ACCLIP flights**

How much of the observed coarse mode particles is mineral dust?

Mineral dust observations during ACCLIP: a first view



PALMS data: Dan Murphy, Gregg Schill et al.

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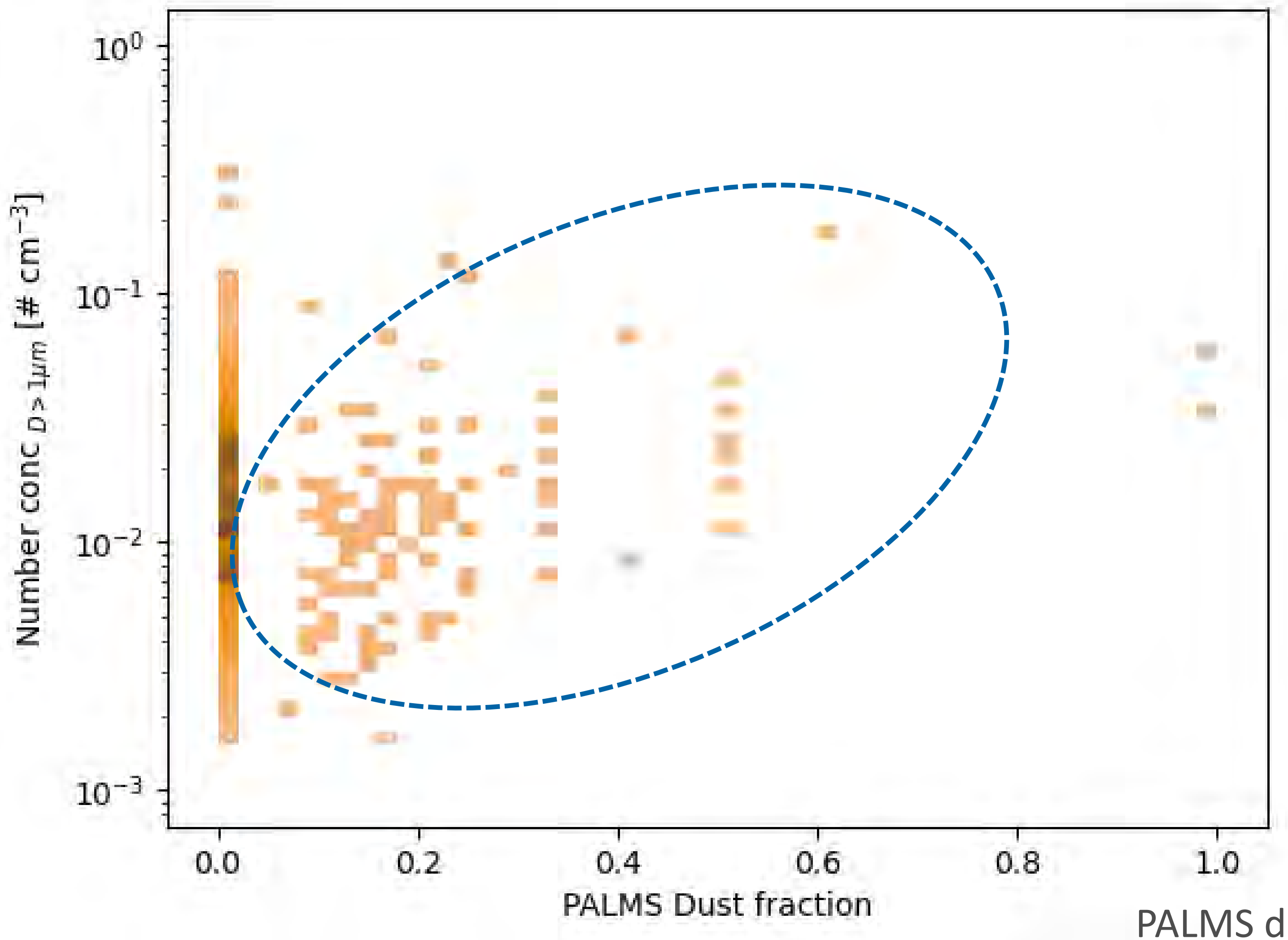

→ **What are the properties of these dust layers?**

→ **How does the dust size distribution compare with dust measurements from the Sahara and Arabian deserts?**

PALMS data: Dan Murphy, Gregg Schill et al.

Summary and outlook

Cold-SABRE 2023

- **Hypothesis: Corse mode particle abundance is different inside and outside the polar vortex**
- **Developed vortex flag** that distinguishes between in-vortex and out-vortex air developed based on UCATS N_2O and MMS temperature. Validated with SF6/“age of air“ data. **Flag can be provided as data file if useful for other analysis**
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ACCLIP 2022

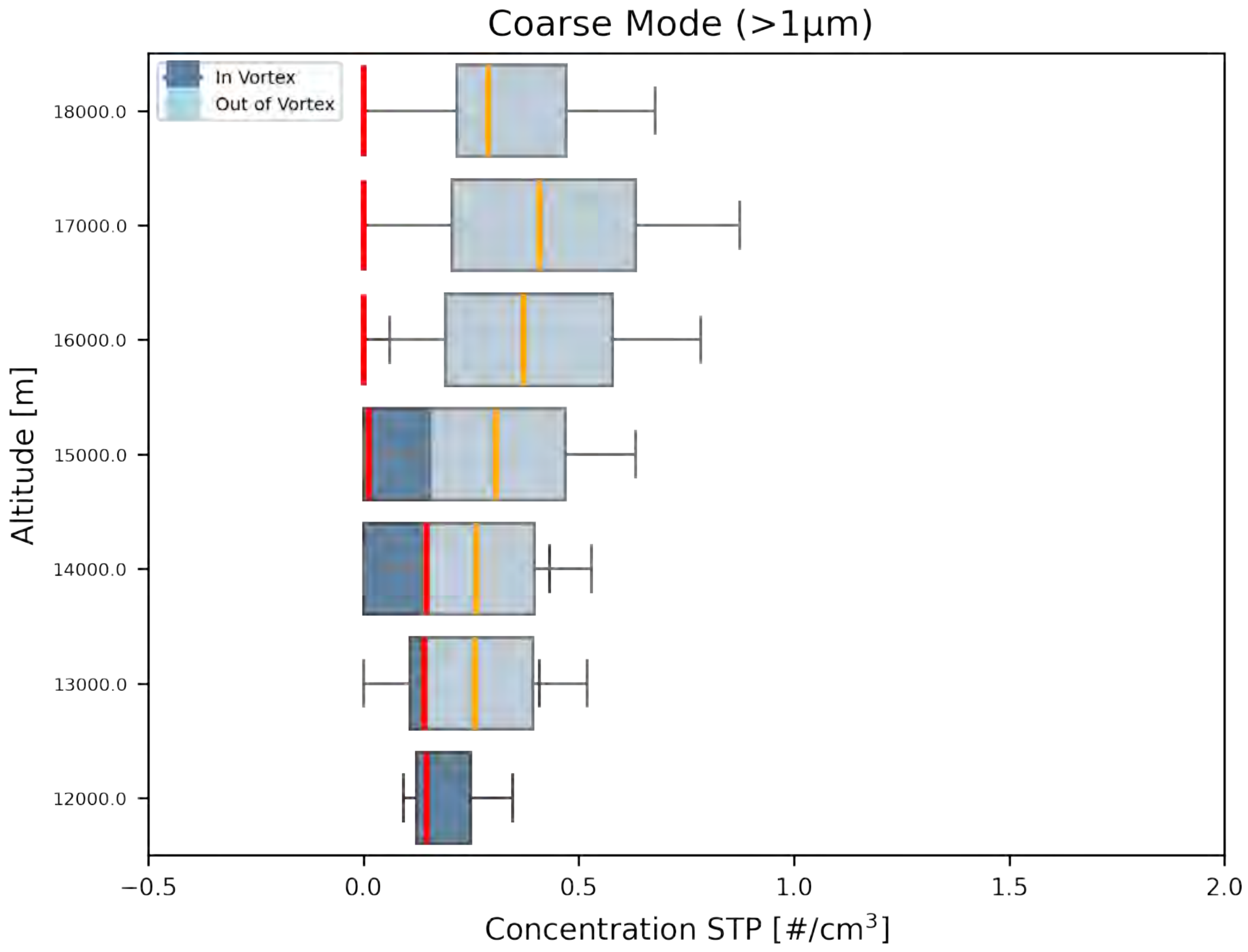
- Ongoing work
- **Interesting finding of non-negligible coarse mode (> 1 µm) aerosol concentration in ALL ACCLIP flights**
- Future analyses will focus on properties of mineral dust layers observed during ACCLIP and compare their properties with dust from the Sahara and Arabian deserts
- **Needed for our analysis:** backward trajectories/aerosol source apportionment, PALMS size-resolved dust information (already in contact with PALMS team)

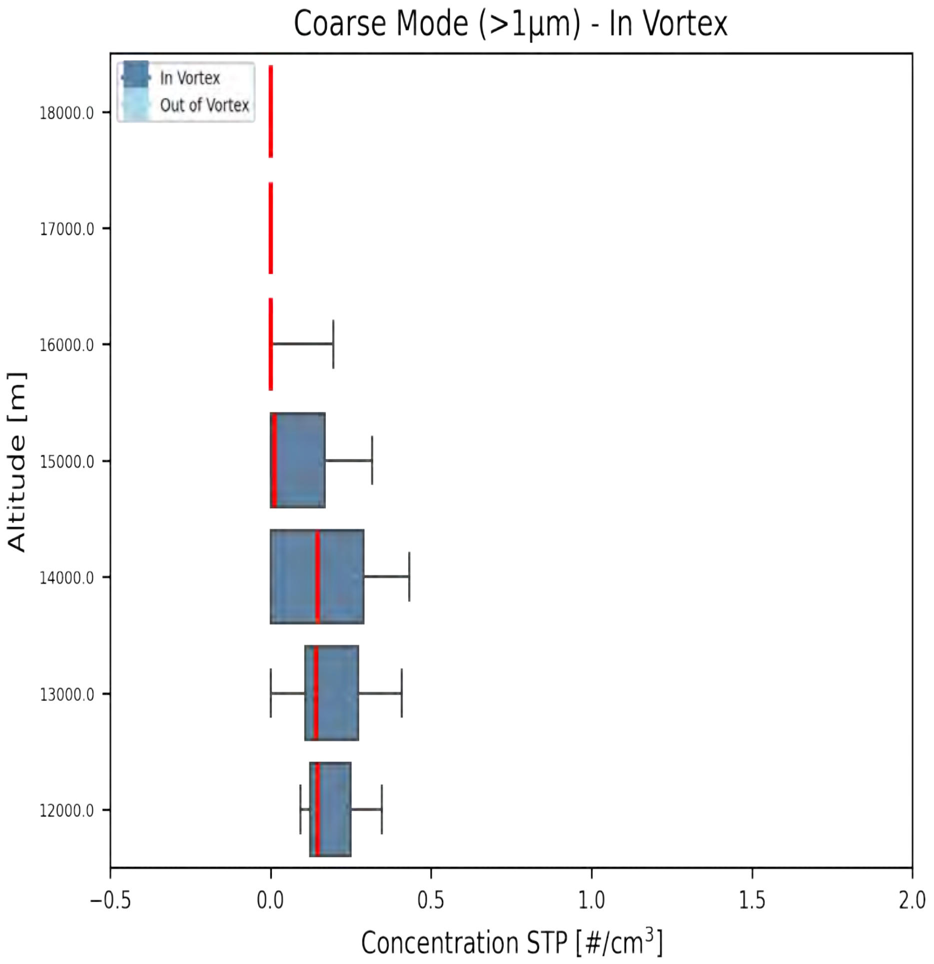
- **An invitation to Vienna: Summer School Basic Aerosol Science: 7 – 13 July 2024**

9th Summer School Basic Aerosol Science: 7-13 July 2024

We hope to welcome you in Vienna!

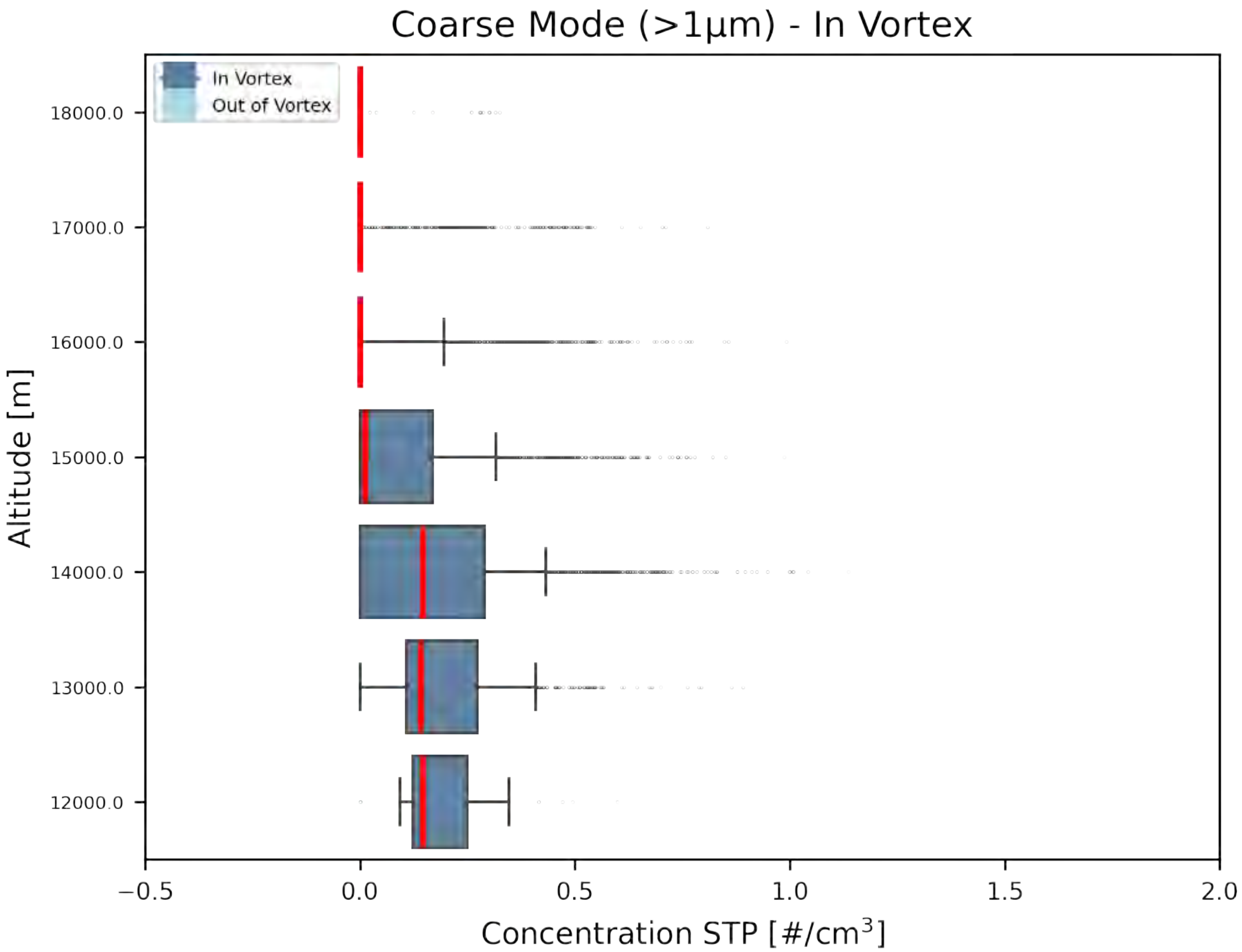
Coarse mode number concentration inside and out of the polar vortex: D_p > 1 µm - I





F. Kuderna (Master thesis Uni Vienna, 2024)

Coarse mode number concentration inside and out of the polar vortex: $D_p > 1$ µm - II



SABRE all flights